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John Ramsbottom

Proceedings of the Institution of Mechanical Engineers 1866 17: 186
DOI: 10.1243/PIME_PROC_1866_017_017_02

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ON AN IMPROVED MODE OF MANUFACTURE OF STEEL TYRES.

By Mr. JOHN RAMSBOTTOM, of Crewe.

In designing the mode of manufacture of Steel Tyres forming the subject of the present paper, the object aimed at by the writer was to reduce the waste of material in the process to so small an amount as to leave its effect insignificant upon the cost of production, and upon the calculation of the weight of ingot required for producing a tyre of given dimensions. Another object was to reduce the time of manufacture, thereby reducing the proportionate cost of plant by turning out more work in the same time.

The ingots are made from Bessemer steel, cast into the moulds shown in Figs. 1 and 2, Plate 59. They are in the form of a cone, 22 inches diameter at the base and 22 inches height, the corners at the base being rounded off. The apex of the cone is cut off at 6 inches diameter, and forms the opening for filling the mould. This is the size of ingot for making a 5 feet tyre, as shown in Figs. 14 to 19, Plate 67. The mould is made of cast iron, in two parts, jointed round the bottom edge, and the upper part fits down flat upon the bottom within four snugs, and is held there by its own weight alone when casting. When the mould is filled, the top of the metal is covered with a thin plate A, and the neck is filled in with wet sand and cottered down in the usual way.

To prevent the cast-iron mould from cracking by unequal expansion whilst the steel is setting, in consequence of the bottom of the ingot being more rapidly cooled than the middle portion, the sides of the mould are made of the curved form shown in Fig. 1, changing in thickness from 4¼ inches thickness at the bottom to 5¼ inches in the middle, and thinning again to 2¼ inches at the neck.

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The bottom is 4 inches thick in the centre, and is protected from cracking by a wrought-iron hoop B shrunk round the outer edge. The centre of the base of the mould is made of fireclay, by inserting a plug C into a tapered hole in the bottom, to prevent the cast-iron bottom from being injured and burnt away by the stream of melted steel when poured into the mould at the top. This fireclay plug is readily renewed when required, being made from the worn out tuyeres of the Bessemer converting vessel.

As soon as the ingot can be removed from the mould it is reheated and then hammered laterally and endways in the manner shown in Figs. 3 to 6, Plates 60 to 62. The hammering is done by the 10 ton horizontal duplex hammer shown in the drawings, the two hammer heads D and E weighing each 10 tons, and moving horizontally towards each other. The cone is first hammered laterally all round its lower edge, as shown in Figs. 3 and 5, the object being to consolidate the skin of the metal and prevent cracking during the subsequent processes. The ingot is supported during the hammering by a carriage F specially constructed for the purpose of allowing the ingot to be rotated whilst being hammered. This carriage is made of boiler plate, mounted upon a cast-iron base-plate G; and the base-plate rests upon the centre bearings J J below, upon which it has a slight rocking motion, allowing the ingot to be adjusted between the two hammer faces, so as to secure the uniform action of the hammers upon it. The hand-lever H H connected with the base-plate G is held by the attendant during working, for adjusting the position of the ingot between the hammer heads. In hammering the ingot laterally, the two wrought-iron swage blocks I I, Fig. 3, are attached to the hammer heads; and a small turntable K, Figs. 3 and 5, supports the ingot at the top of the carriage F, allowing it to be rotated horizontally between each blow, by means of a fork which lays hold of the ingot like a spanner. This turntable is carried on a vertical centre pin, dropped into a cast-iron socket; and it is lifted out when the side hammering of the cone is completed.

The ingot is then canted over on its side, and hammered in the direction of its axis, as shown in Figs. 4 and 6, until it is reduced to

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9 inches height, as shown in Fig. 15. The hammer head D, which acts upon the apex of the cone during this process, is narrower than the other head, and has the effect of spreading out the narrow apex more effectually than would otherwise be the case. In this position the cone rests upon the four rollers L L and M M contained in the body of the carriage F. Two of these rollers M M, carrying the large end of the ingot, are 10 inches diameter by 9 inches length and 1 inch tapered, and remain fixed in position. The other two rollers L L are 9 inches diameter and $1\frac{1}{2}$ inch thick, and are carried in a cast-iron frame which slides vertically within wrought-iron guides, and is supported by a long wrought-iron wedge N, Figs. 5 and 6. This wedge, which is 7 feet 10 inches long, is driven home at the commencement of the hammering, and is gradually drawn out so as to lower the supporting rollers by degrees, and accommodate their height to the increasing diameter of the centre of the ingot during the hammering. The rate of withdrawing the wedge N is regulated by the attendant, who has thus complete facility for adjusting the ingot constantly to its true level between the two hammers with as great accuracy as if he were holding it by hand. The taper in the two fixed rollers M M, Fig. 4, allows for the slight increase in diameter of the base of the ingot, which advances downwards towards the small ends of the rollers as the hammering proceeds. The ingot is continually turned round upon these rollers during the hammering by means of ordinary pinch bars.

The bloom, which is now in the form of a flat disc 22 inches diameter and 9 inches thick, as shown in Fig. 15, Plate 67, has then a hole punched in the centre to form it into a ring, by the punching hammer shown in Figs. 7 to 10, Plates 63 and 64. This is a 5 ton vertical hammer, having a projecting cone O upon the hammer face, 17 inches length and 12 inches diameter at the base, with a rounded apex. This cone is of cast steel, in one piece with the hammer face P; and a hole is first punched in the centre of one side of the bloom extending nearly through its thickness. The bloom is then turned over upon the anvil, and the conical punch is driven through from

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the other side, this process being repeated until the hole in the bloom is enlarged on both sides to the size of the base of the conical punch, as shown in Fig. 16. The flat hammer face P, which is prolonged on each side of the punch, as shown in Fig. 7, then acts upon the bloom, and hammers it down in thickness, the bloom being turned round horizontally between each blow. By this means the bloom is brought to 31 inches diameter and $5\frac{3}{8}$ inches thickness, with a centre hole 11 inches diameter in the middle, as shown in Fig. 17. The anvil block Q is made with a hole all down the centre, large enough to give clearance to the punch in its lowest position, as shown in Fig. 9; but in order to prevent the centre portion of the bloom from being driven down into this hole at the commencement of the work, the hole is at first contracted in size by a steel ring R, Figs. 8 and 10, dropped into a recess at the top. This ring is afterwards removed when the punching of the hole has been partly completed on one side of the bloom.

In order to afford facility for turning the bloom over quickly upon the anvil of the punching hammer, a swing frame S is employed having two centre screw pins, which seize the bloom a little below its centre of gravity. These screws are tightened up by hand for laying hold of the bloom, and after it has been turned over they are slackened back again, and the swing frame lies on the ground out of the way during the hammering. When in use the outer end of the swing frame is connected by a chain to the hammer head, as shown in Fig. 7, so that the frame and bloom are lifted by the hammer, and the bloom turns over by its own weight, thus requiring no crane. During the hammering the bloom is turned round horizontally upon the anvil by means of ordinary pinch bars.

The next operation is hammering out the bloom edgeways, in order to enlarge the centre hole, which is done upon the beck anvil shown in Figs. 11 to 13, Plates 65 and 66. The side of the anvil T is inclined at 20° to the vertical; and the beck iron U, which stands out at 81° to the side, projects 10 inches and is $11\frac{1}{2}$ inches diameter at the base. The bloom is rotated vertically between each blow of the hammer by means of a pinch bar V, Fig. 12, suspended by a

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chain from the top of the hammer framing. After the hammering on the beck is finished, the bloom is laid flat on the top of the anvil and hammered all round, as shown in Fig. 13, whereby the slight increase of width produced by the spreading on the beck is hammered down to the final width of $5\frac{3}{8}$ inches, as shown in Fig. 18, Plate 67. After the completion of each process, any cracks which may appear on the surface of the metal are chipped out.

By this hammering the bloom is brought to 34 inches diameter, with the centre hole 19 inches diameter; and it is then finished in the circular rolling mill, the well-known ingenious invention of Mr. Rothwell Jackson, one of the Members of the Institution, which brings the bloom to the form and dimensions of the finished tyre, as shown in Fig. 19, by rolling it at the same time both outside and inside without altering the width. This machine completes the rolling of the bloom into a finished tyre at one heat, the time occupied being about $5\frac{1}{4}$ minutes in the rolling machine.

The whole of the above process for the manufacture of the tyre is effected in four heats after the original casting of the ingot, which is taken from the mould as soon as the metal has set, and is then reheated for the first time before being taken to the horizontal duplex hammer. The second heat is in preparation for the punching of the centre hole, after which the bloom is again reheated for the beck anvil; and the fourth heat is for the final rolling of the tyre in the circular rolling mill. When the arrangements are fully completed, it is expected that the number of heats will be reduced to three, by avoiding the necessity for the present second reheating of the ingot immediately on leaving the duplex hammer; and that the red heat of the ingot will never be lost from the time of casting till its completion as a finished tyre.

As an illustration of what can be accomplished with the present appliances, it may be named that in one instance the metal for making six steel tyres was run into the casting ladle from the large Bessemer converter at 6 5 a.m., the rolling of the first tyre was completed at 10 15 a.m., and the last tyre at 11 17 a.m.; making only 5 hours 12 mins. for the completion of the whole six tyres.

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This mode of manufacture of tyres allows of all the material in the original ingot being used up in the finished tyre; a very trifling amount of metal alone is punched out in first forming the centre hole, and the material is afterwards simply displaced laterally and gradually worked outwards from the centre, as the hole is expanded from the beginning to the end of the process. The top of the conical ingot, instead of being cut off as a crop end of the full area of the ingot, as in the ordinary mode of manufacture from a parallel ingot, is reduced to only 6 inches diameter, which being in the centre of the ingot is at the part worked through by the punch, and remains at the inner side of the finished tyre, thus avoiding any risk of affecting the wearing face of the tyre. As another consequence of the very small area of the top of the ingot, the covering plate required in casting is so small and so thin that it is lost in the first reheating furnace by oxidation.

The saving of waste of material in this mode of manufacturing steel tyres has the important advantage not only of reducing the cost of manufacture, but also of allowing the total quantity of metal to be adjusted beforehand with great accuracy for the required size of tyre. Thus the 5 feet tyres, the size to which the dimensions of ingot previously given apply, are made from an ingot weighing 8 cwts., and the weight of the tyre finished from the rolls is a little more than $7\frac{1}{4}$ cwts.; so that the total loss by reheating in the process of manufacture is only 8 per cent. The required weight of ingot can therefore be calculated and provided for any given size of tyre; and the form of the ingot with the small area at top ensures a degree of uniformity not otherwise attained in the weight of the castings, as the whole extent of variation possible in the height of the ingot cannot cause any appreciable difference in the size of the finished tyre.

By this mode of manufacture of the tyres it will be seen that a very large amount of work is put into the ingot by the successive hammerings, before it enters the final rolling mill; and the effect of this in the writer's opinion is to cause a very considerable improvement in the quality of the tyres, rendering the metal mild and tough in a remarkable degree. The broken tyre that was

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exhibited to the Members, when visiting Crewe yesterday, required nine blows from a weight of $21\frac{1}{2}$ cwts. falling from a height of $22\frac{1}{2}$ feet to break it.

Colonel KENNEDY was sure all the Members had been highly gratified by the excellent opportunity afforded them on the previous afternoon of witnessing the manufacture of the steel tyres at the Crewe Steel Works, and seeing the very admirable manner in which the whole of the operations were there carried out for the manufacture of locomotive work, together with the many important improvements that had been introduced. From the very valuable paper that had been read it would be seen with what complete success the Bessemer process had now been applied to the manufacture of tyres; and he should be glad to know some further particulars respecting the durability of the steel tyres in comparison with the best iron tyres, as he had always expected the material produced by the Bessemer process would give superior results to iron for such purposes.

Mr. J. L. ASHBURY remarked that it appeared from the paper that attention had hitherto been confined to locomotive tyres, as no reference was made to carriage tyres; and the applicability of the steel tyres for railway carriages and wagons must of course depend upon their relative cost as compared with the present carriage and wagon tyres of Yorkshire iron weighing about $3\frac{1}{2}$ cwts. each and costing £22 per ton. At the present time there was no doubt whatever that a strong feeling prevailed among engineers in favour of steel tyres, more particularly for locomotive engines and tenders; but in the case of a large stock of as many as 15,000 or 20,000 railway carriages and wagons, there must of course be great

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hesitation in adopting the Bessemer steel tyres if the cost were anything like as much as that of the cast steel tyres made of crucible steel, costing about £35 per ton. It was not any question of the quality of the steel tyres which retarded their adoption for railway carriages and wagons, but solely a matter of reduction of cost, as there appeared no reason to doubt that the steel tyres would have an advantage in durability over the present iron tyres. At the present time however, both in this and other countries, it was the exception and not the rule to have steel tyres; and a very considerable reduction in cost must take place before steel tyres could be generally introduced. There seemed some reason to anticipate such a reduction in the course of a few years' time, as far as could be inferred from the case of the Bessemer steel rails, the cost of which had originally been as much as £18 per ton, but was now reduced to only £12 per ton. The actual mileage of the steel tyres in comparison with iron tyres was another point upon which the general adoption of the steel tyres would depend, and this required to be very thoroughly ascertained. He suggested that the adoption of steel tyres for carriages and wagons would be very materially accelerated if it were possible to combine a steel face with a scrap-iron back in the tyres, whereby the cost would be greatly reduced below the present amount of £35 per ton for steel tyres, and would more nearly approximate to the cost of £22 per ton for best iron tyres.

Mr. RAMSBOTTOM replied that he had great reason to be satisfied with the results thus far obtained from the adoption of the Bessemer steel tyres for locomotive engines and tenders; he had become convinced previously that this material was the right one and completely safe for such purposes, having himself tested it in a variety of ways, both for axles, piston rods, and other purposes; and he had therefore felt no hesitation in recommending that the necessary plant should be put down for producing the Bessemer steel and manufacturing the tyres, having satisfied himself that a saving would be effected by the use of the steel tyres, and that it would be so far advantageous to manufacture them at the locomotive works at Crewe.

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In the production of the metal in the converting vessel, he had followed Mr. Bessemer's instructions very closely; but in the subsequent treatment of the bloom he had departed from the beaten track by introducing the horizontal duplex hammer, together with the other special modes of roughing down the tyres into shape before rolling, which had been described in the paper and seen by the Members on the previous day, whereby the amount of labour expended upon the manufacture of the tyres was much reduced, while the work put into them was largely increased by the great amount of effective hammering that the bloom underwent. For the suggestion of the fireclay plug in the centre of the bottom of the casting mould he was indebted to his assistant, Mr. Webb; this was found very advantageous, and he thought the same plan might be adopted with advantage in other moulds, particularly where the melted metal had to fall from some height upon the bottom of the mould, so as to allow of that part of the bottom being readily renewed when it became worn. In reference to the hammering on the beck anvil, an improvement was now being made which he expected would supersede the beck hammer altogether, and reduce the time of that part of the process from about fifteen minutes as at present to probably not more than about two minutes; the whole operation being performed by a machine which he had designed for the purpose. The present method of hammering on the beck iron had first been brought under his notice by Mr. Allen of the Bessemer Works at Sheffield, to whom he was also indebted for the plan of giving the plain bevilled edge to the bloom, as shown in Fig. 18, Plate 67, for forming the flange of the tyre; and it was found in practice that this plain bevil was quite sufficient preparation for making the flange by the final rolling in the circular rolling mill, and was a most effectual means of obviating all necessity for forging a flange upon the bloom in the previous processes.

With regard to the durability of the Bessemer steel tyres, he was not yet in a position fully to compare them with the best Yorkshire tyres and Krupp's cast steel tyres from actual experience, as they had not yet been at work long enough for the purpose; but judging from the known durability of the material in other cases he had no

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doubt that the new tyres would last for a very much longer mileage than the best Yorkshire tyres, and if not actually equal to Krupp's tyres would certainly approach them very nearly in durability. He had not used any tyres made with a scrap-iron back and steel wearing face, such as had been suggested, and had not yet applied the steel tyres to carriages and wagons, as the whole productive powers of the works had hitherto been fully occupied with the manufacture of locomotive tyres alone; but it was intended ultimately to carry out the same system for supplying the whole of the rolling stock with the steel tyres. For securing the tyre to the wheel a number of modes had been tried, and he had now five different methods in operation, which were being watched in order to determine the best plan; and his present opinion was that the ordinary attachment by means of rivets through the tread of the tyre would be found to outlast all the others.

The great object which he had had in view in adopting the Bessemer steel for tyres and carrying out the mode of manufacture described in the paper had been to obtain tyres of a mild quality of steel, which could be thoroughly relied upon for safety in running, as he considered it was of primary importance to look very closely to the question of safety for working in the manufacture of every portion of railway rolling stock. A practical proof of the safety of the Bessemer steel tyres was furnished by the tyre exhibited to the Members at Crewe on the previous afternoon, which had required the very severe treatment described in the paper in order to break it. Another of the tyres had been even more severely tested, and the value of the test would be readily understood by all in the habit of working steel. This tyre was a defective one, which had been made in one of the earlier experiments on the manufacture of the steel tyres, and it was very much cracked about the flange. It was first tested at a dull red heat upon the ordinary tyre-blocking press by hydraulic pressure; and this failing to produce any perceptible stretching, it was subsequently heated to a bright red heat and dropped tight upon a cast-iron block, and then suddenly quenched with cold water to make it shrink violently; but even by this treatment the tyre was not broken, though it was stretched about

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$\frac{3}{4}$ inch in circumference. From these results he was confident that the Bessemer steel tyres of this mild quality were much better and safer than the best description of welded iron tyres; and quite as safe as weldless tyres of any description, whether iron or steel, irrespective of the mode of fastening the tyre on the wheel. The aim in adopting the Bessemer tyres had not been so much to obtain the highest scientific results, as the best commercial results, making safety in running the first consideration and keeping also in view the question of practical economy; and it was quite possible consequently that the material which was found so suitable for the tyres might not be so well adapted for other first-class engineering purposes as the best crucible cast steel.

Mr. F. J. Bramwell remarked that the test which had been mentioned, of heating one of the steel tyres and shrinking it on a cold solid block of cast iron, would be fully appreciated as a most satisfactory demonstration of the thorough safety under all circumstances of tyres made of that material in the manner described in the paper.

Mr. W. Fairbairn enquired what had been the experience in the manufacture of the Bessemer steel tyres as to the uniformity in the quality of the material from which they were made. The difficulty attending the Bessemer process was not the actual production of the steel, but its production with sufficient uniformity of character, and it was very desirable to arrive at something closely approaching to practical uniformity. The practice was to add a given proportion of carbon to each charge of metal in the Bessemer converting vessel, in order to convert the metal into steel; but nevertheless the steel produced by this means did not always bear a uniform character. In the testing of iron boiler plates and ship plates he had found such a wide variation in the quality that some had double the strength of others; and as the strength of any structure was only equal to that of its weakest part, it was very desirable that uniformity should be arrived at in the manufacture of iron plates, and for the same reason this was equally important in the case of the steel tyres.

Mr. Ramsbottom replied that the question as to the uniformity of quality of the Bessemer steel was a very important one, and he

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thought it could now be fairly met by the results of experience. In dealing with iron there was a wide range of quality, and almost as great a range was found in steel. But comparing the Bessemer steel with crucible steel, the former was liable to a less extent of variation in quality than the latter, while the gradations of quality were as clearly discernible; and therefore at least as near an approach could be made to uniformity in the quality of the Bessemer steel as in crucible steel. He had indeed met with tyres made of crucible steel which had proved so hard that it had been almost impossible to turn them; but in his opinion this was much less likely to happen with the Bessemer steel. In the case of iron plates for boilers and other purposes, uniformity of strength might easily be ensured by rolling the plates rather larger than was required, and having a piece cut off each separate plate and tested; but for many purposes, such as girders, he thought plates of Bessemer steel would be safer and stronger than iron plates, on account of the soft and tough quality of the material. In connection with this point too little attention he thought was paid to the change of form occurring under strain, as a criterion of the practical value of any material, and to the amount of work that must be expended in producing this change of form before fracture could be effected. An illustration was afforded by the fact that a steel bar 12 inches long and requiring a tensile strain of 15 tons per square inch to break it might be elongated only $\frac{1}{4}$ inch before breaking, whilst an iron bar of the same length and requiring only half the tensile strain per square inch to break it might undergo three or four times as much elongation before breaking; and in like manner, to burst a bottle of lead by hydraulic power would require more work to be expended in pumping than to burst a glass bottle of the same dimensions; and the case was similar in regard to strains of compression. Thus a material which was the weaker in respect of its ultimate breaking strain might in one sense be the stronger; and hence the value ot toughness in the material employed for such purposes as girders and boiler plates.

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The PRESIDENT moved a vote of thanks, which was passed, to Mr. Ramsbottom for his paper, and for the excellent opportunity afforded to the Members on the previous afternoon of witnessing the whole process of the manufacture of the steel tyres at the Crewe works.

The following paper was then read:—

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Fig. 1. *Vertical Section of Casting Mould.*

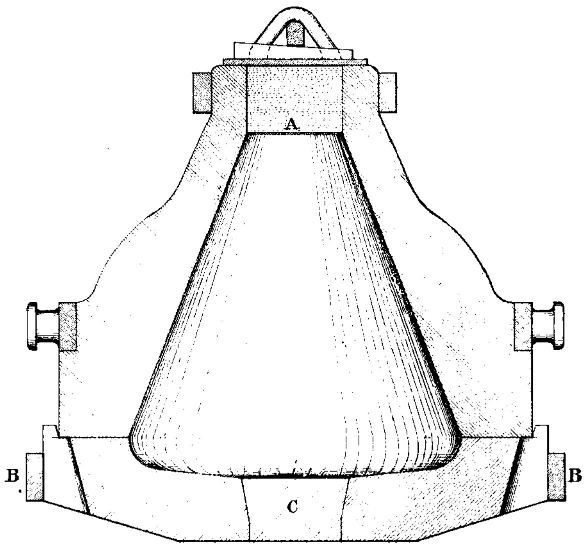
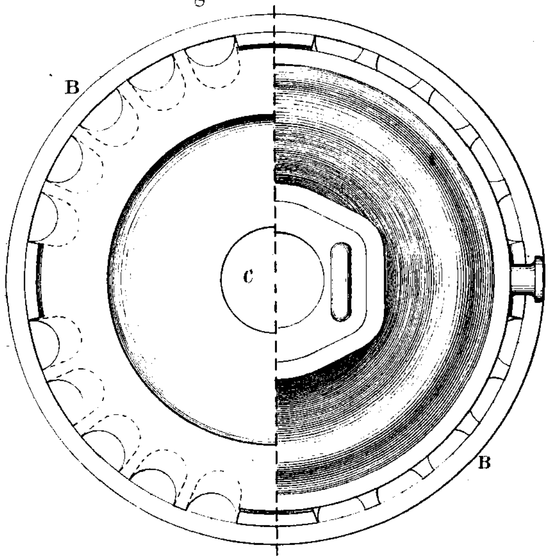


Fig. 2. *Plan.*



(Proceedings Inst. M.E. 1866. Page 186.) *Scale 1/12 th.*

10 5 0 10 20 30 *Inches.*

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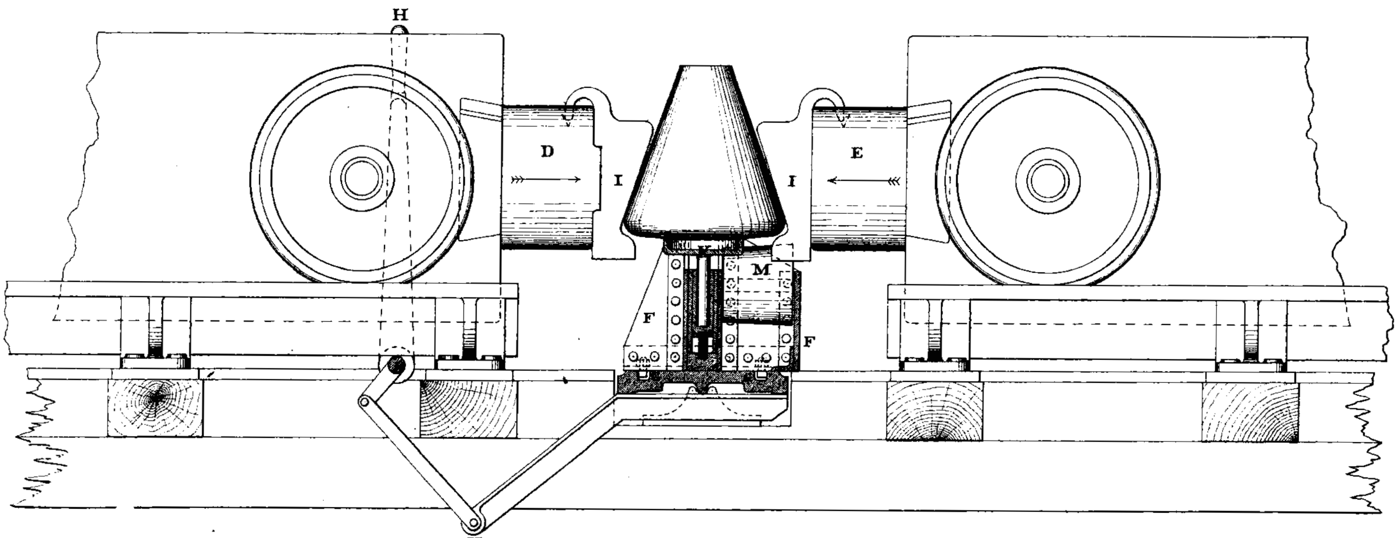
Fig. 3. *Side Elevation of Horizontal Duplex Hammer, hammering Bloom laterally.*



(Proceedings Inst. M. E. 1866. Page 186.) *Scale 1/24th* Ins. 12 6 0 1 2 3 4 5 Feet.

Fig. 4. Side Elevation of Horizontal Duplex Hammer, hammering Bloom endways.

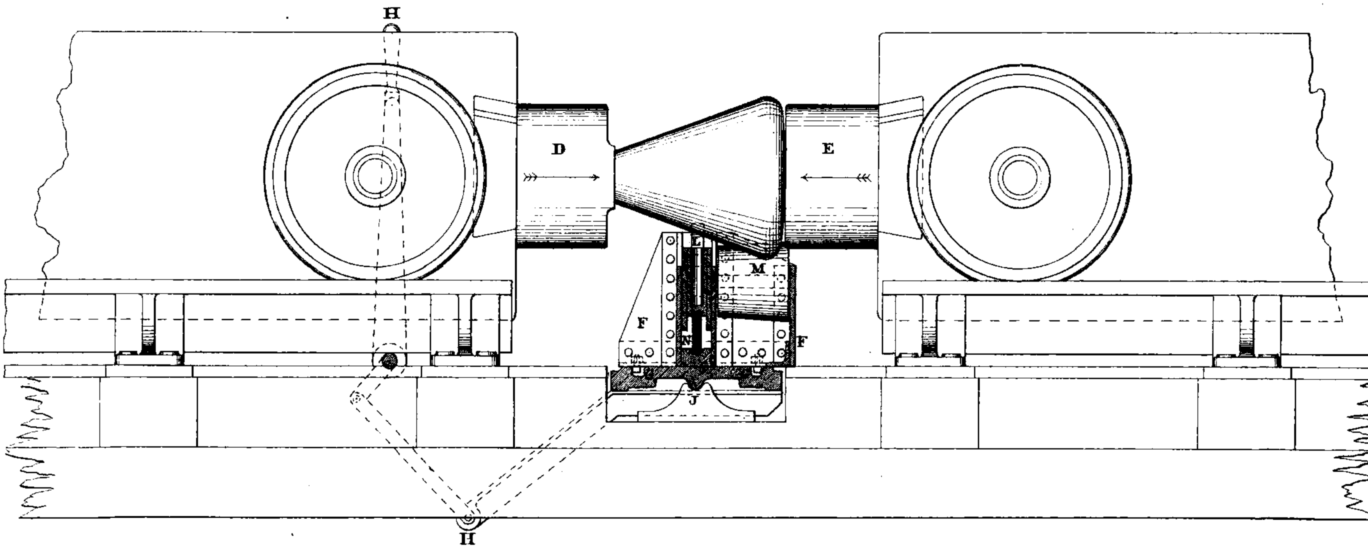


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Fig. 5. *Transverse Section of Horizontal Duplex Hammer, hammering Bloom laterally.*

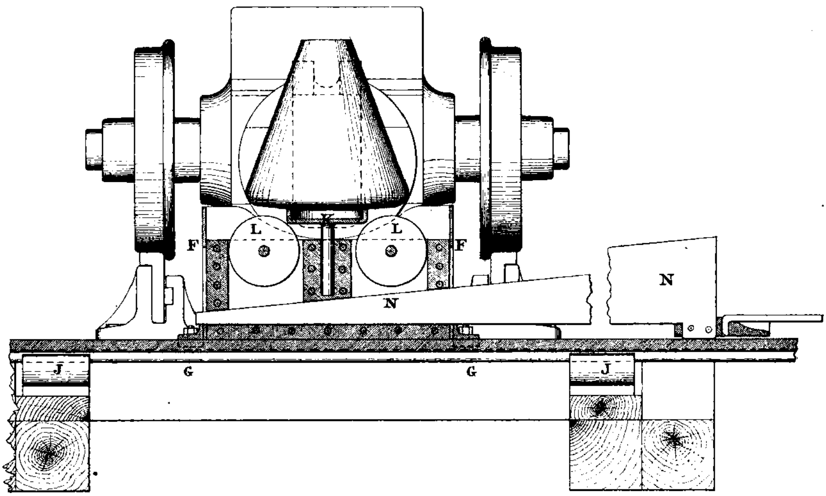

Fig. 6. *Transverse Section of Horizontal Duplex Hammer, hammering Bloom endways.*

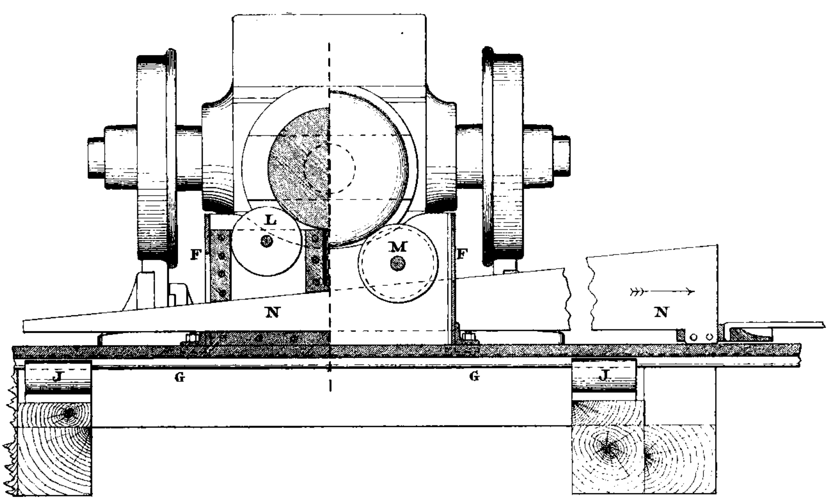

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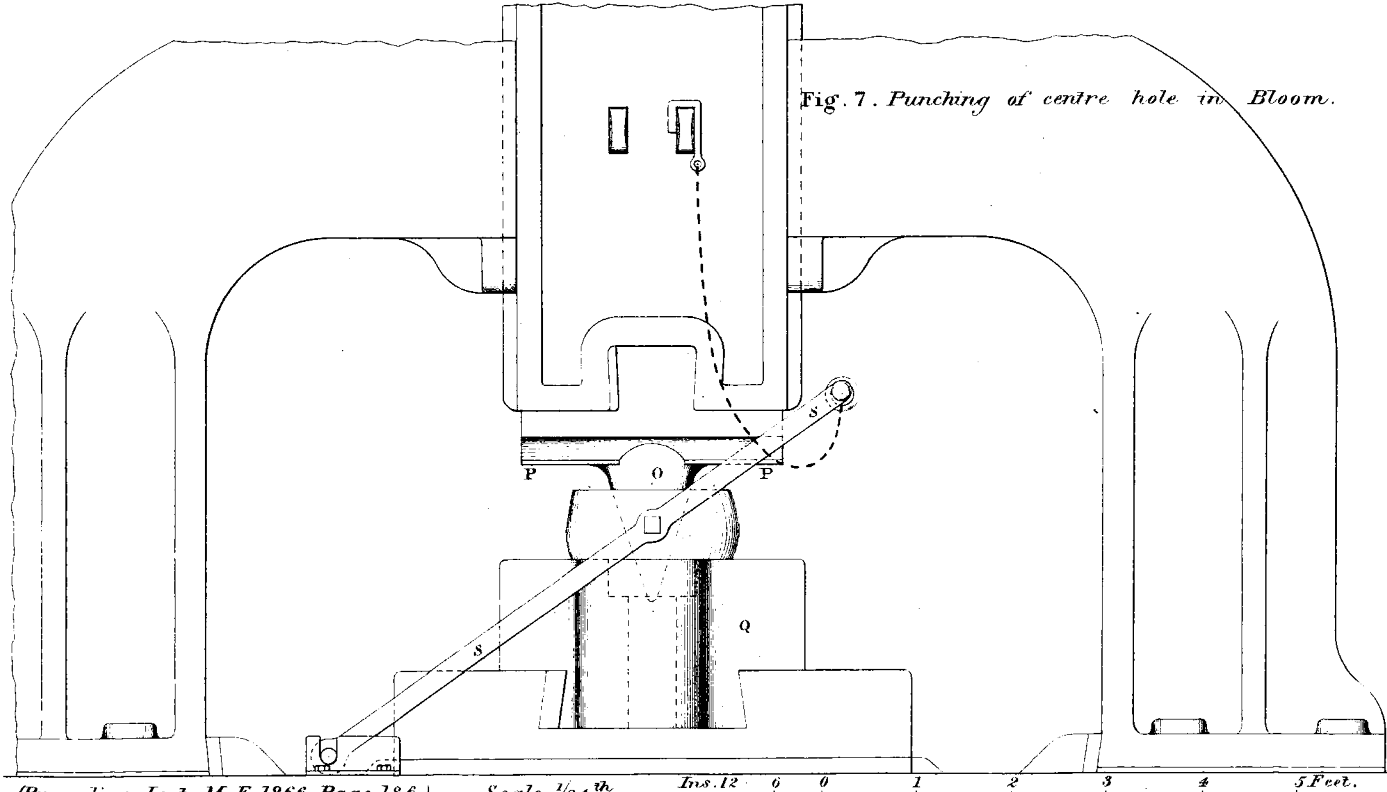
Fig. 7. Punching of centre hole in Bloom.



(Proceedings Inst. M. E. 1866. Page 186.) *Scale 1/24th.*

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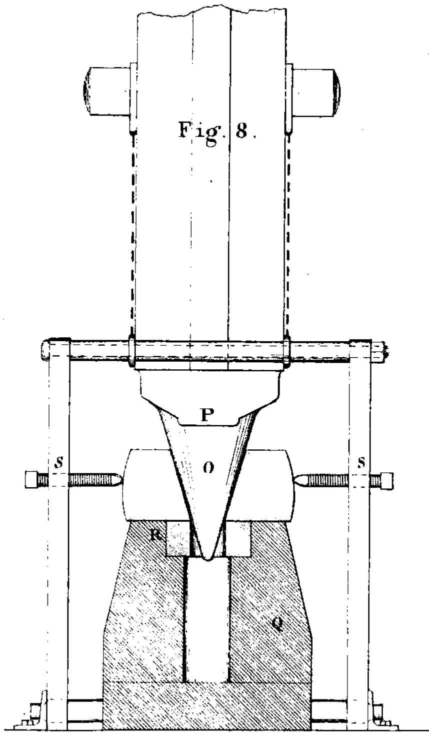
MANUFACTURE OF STEEL TYRES.

Plate 64.

Punching of centre hole in Bloom.



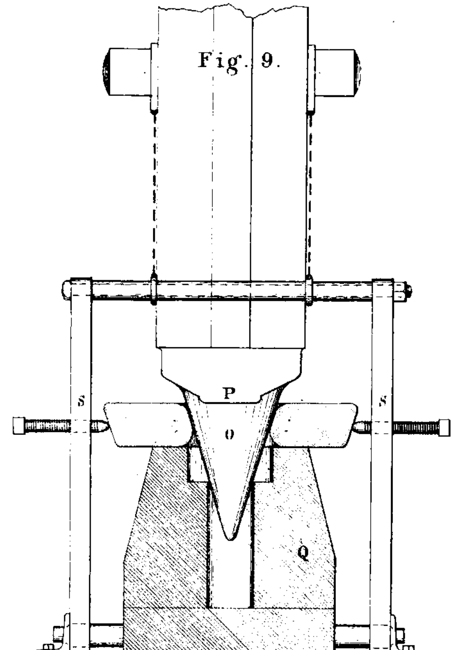
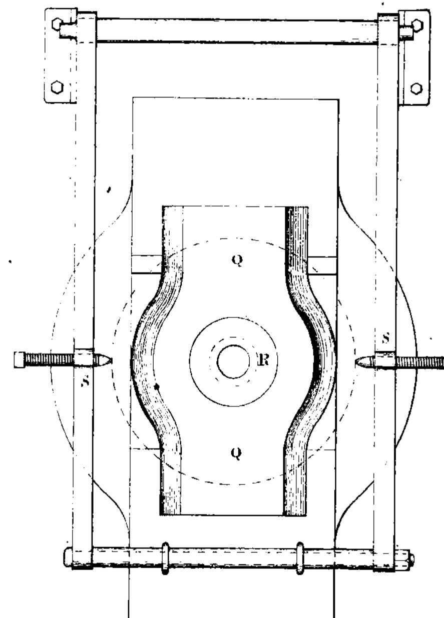


Fig. 10. *Plan of Anvil Block and Swing Frame.*



(Proceedings Inst. M. E. 1866. Page 186.) *Scale 1/24th*

Ins. 12 6 0 1 2 3 4 5 Feet.

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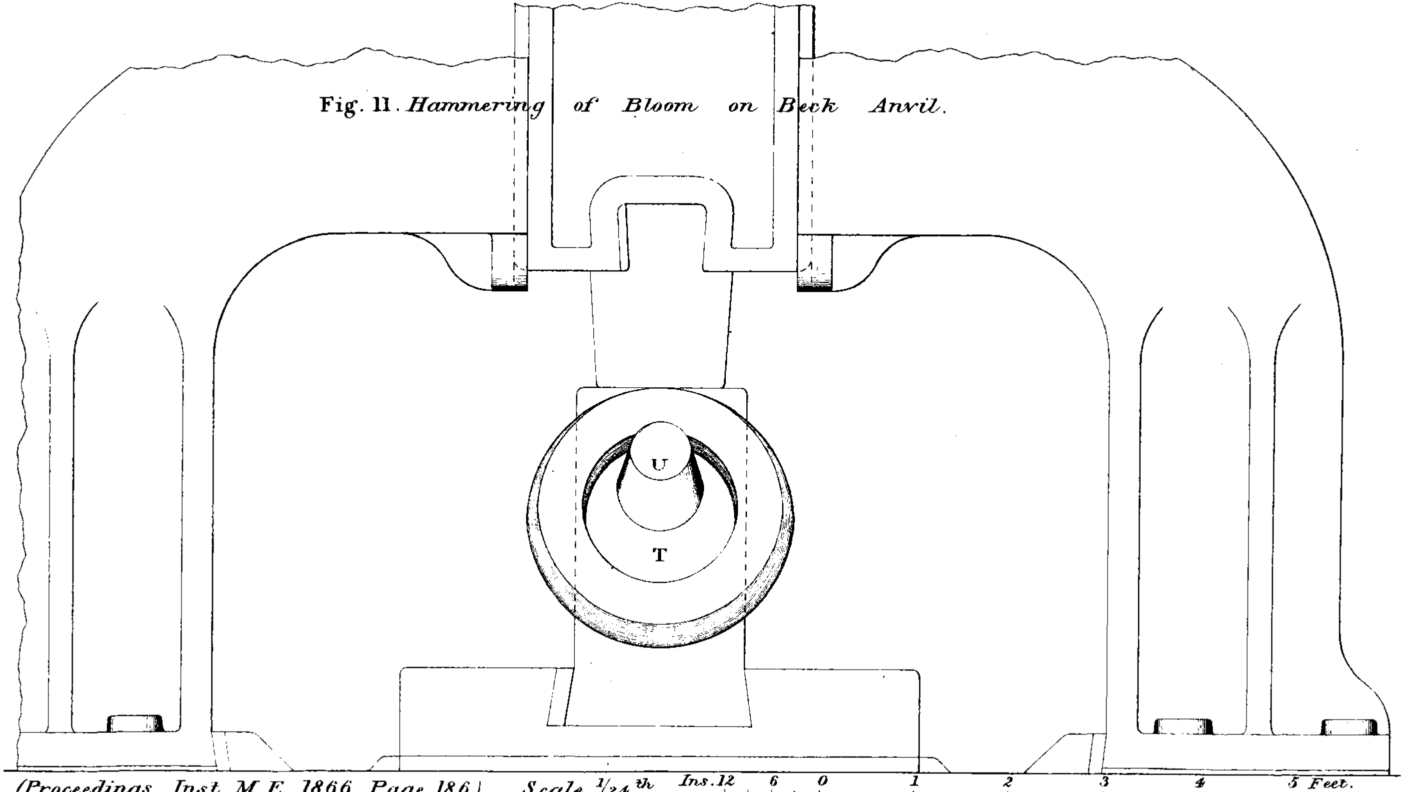
Fig. 11. *Hammering of Bloom on Beck Anvil.*



(Proceedings Inst. M.E. 1866. Page 186.) *Scale 1/24th.*

MANUFACTURE OF STEEL TYRES.

Plate 66.

Hammering of Bloom on Beck Anvil.

Fig. 12.

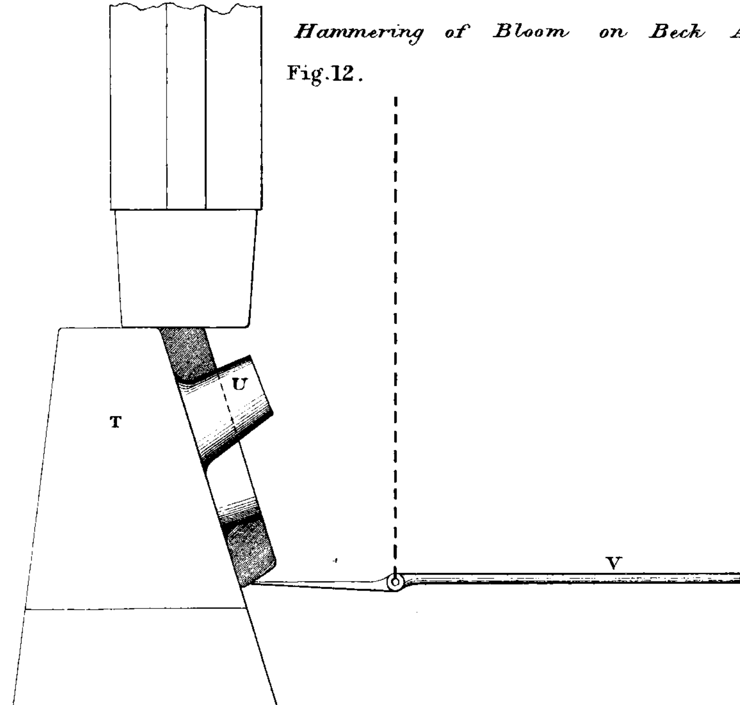
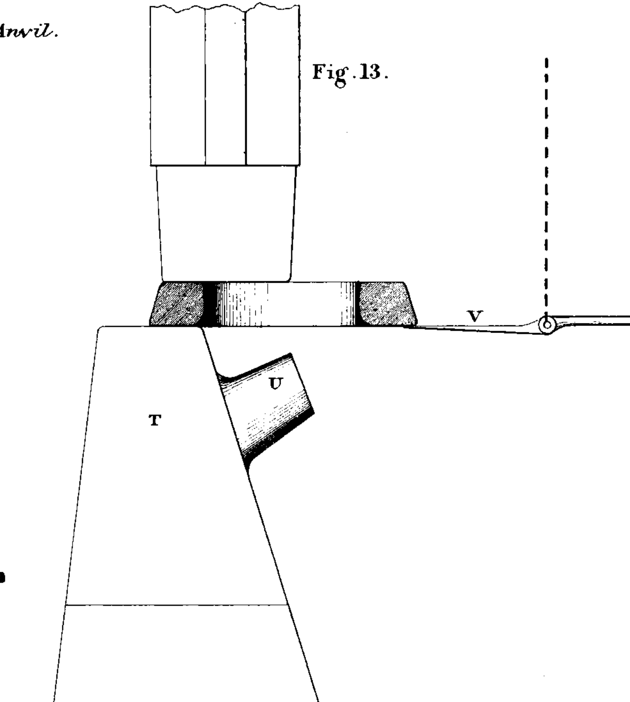


Fig. 13.



(Proceedings Inst. M.E. 1866. Page 186.) *Scale 1/24th.* Ins. 12 6 0 1 2 3 4 5 Feet.

MANUFACTURE OF STEEL TYRES.

Fig. 14. *Steel Ingot from Casting Mould.*

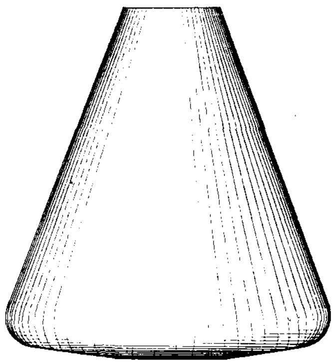


Fig. 15. *Hammered Bloom from Horizontal Duplex Hammer.*

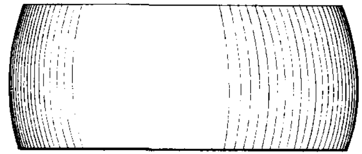


Fig. 16. *Centre hole punched.*

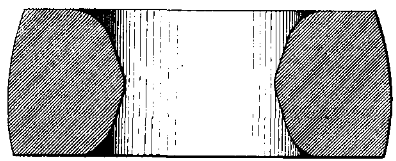


Fig. 17. *After working under Punching Hammer.*

Fig. 18. *After hammering on Beck Anvil.*

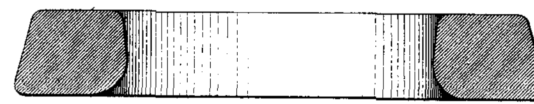
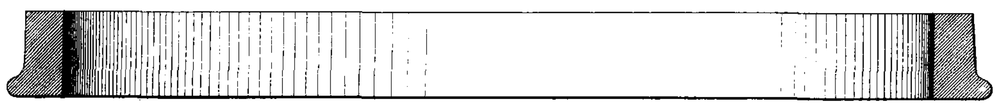


Fig. 19. *Finished Tyre from Circular Rolling Mill.*



(Proceedings Inst. M.E. 1866. Page 186.) *Scale* $\frac{1}{12}$*th*

10 5 0 10 20 30 *Inches.*