

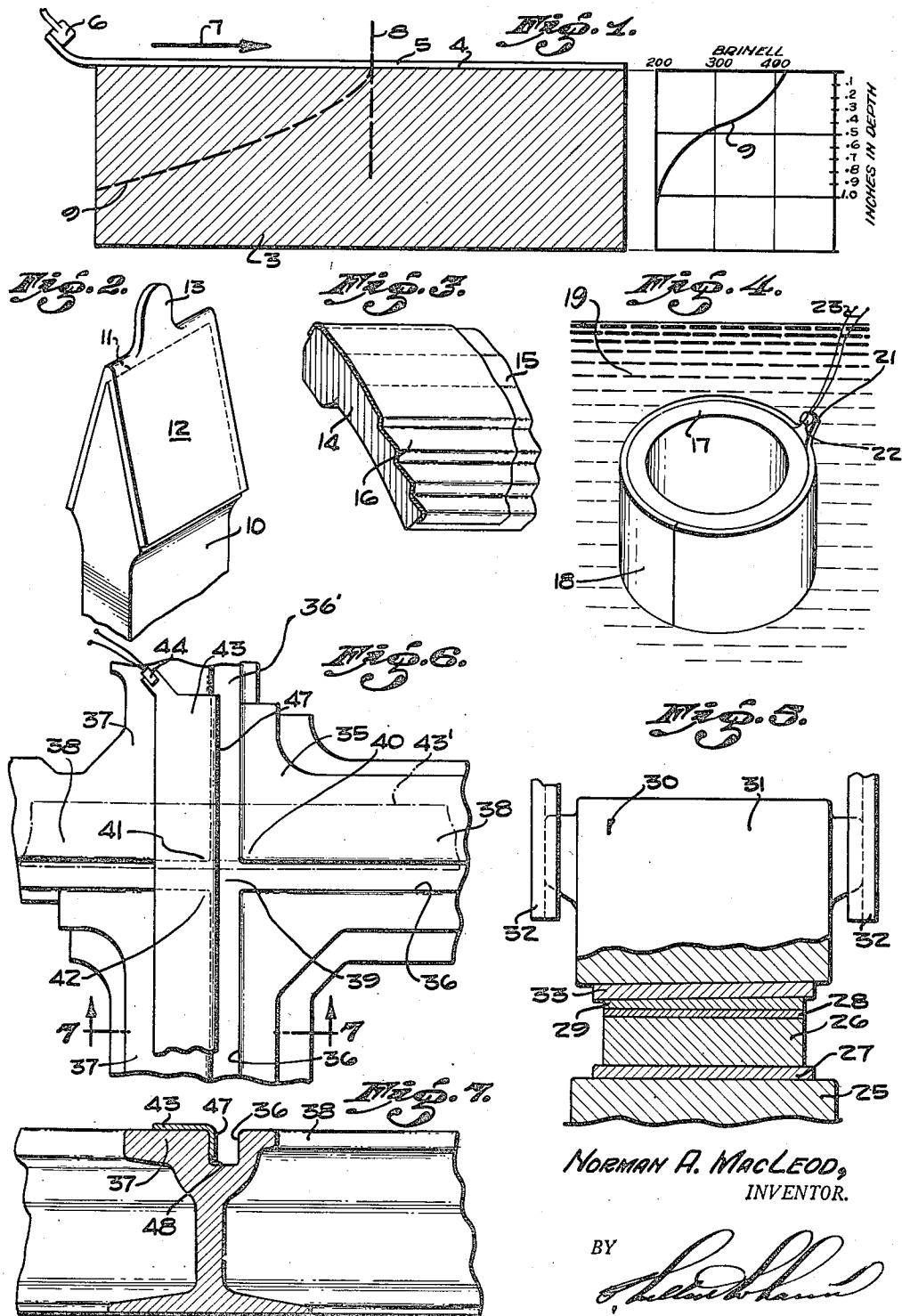
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METHOD OF HARDENING MANGANESE STEEL

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METHOD OF HARDENING MANGANESE STEEL

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My invention relates to methods for hardening manganese steel which is generally identified as austenitic manganese steel or Hadfield's manganese steel.

When cast this manganese steel upon being quenched usually has a hardness ranging from 180 to 230 Brinell. Manganese steel may be work-hardened by conventional means to a hardness sometimes in excess of 500 Brinell.

Manganese steel has many special uses for which it is particularly adaptable due to the fact that when hardened, it becomes a very hard and tough material. It also possesses the especial virtue of hardening under impact applied during working conditions. At the same time, it possesses certain weaknesses and deficiencies which it is a purpose of this invention to obviate or correct. For instance, the work-hardening of manganese steel prior to actual work conditions produces a very hard surface or skin while the underlying sections remain relatively soft. This means that when heavy pressure is applied to the manganese casting or other object, a flow or deformation or distortion of the metal structure underlying the surface is likely to occur. Efforts for many years have been made to overcome that particular type of weakness but to the date of this invention, no known method of hardening which would produce any substantial amount of consistent hardening beneath the surface has been developed.

Manganese steel is used extensively for steel castings of various types: dredging and excavator buckets; conveyor, elevator and transmission chains; crusher grinding mill and pulverizer parts; power shovel dippers; dredging pumps; material handling pumps; welding materials for reclamation and hardfacing; car, crane, gear, sheave and sprocket wheels; railroad crossings; brake shoes and lockers for railroad cars and locomotives; and various other products. One manufacturer of manganese steel castings and other objects advertises manganese steel as "the toughest steel known" and points out that the work-hardening and abrasion resistant properties of manganese steel give long life under the severest service conditions.

It is an object of the present invention to provide simple and effective methods of work-hardening which will replace the shotpeening and hammering which are now employed and which require a great deal of time and expense without producing the optimum conditions of hardness required for maximum service from manganese steel castings. Where shotpeening is employed there is a hardening of the surface sometimes to a hardness of about 500 Brinell, but the hardening effect of the shotpeening does not usually extend to a depth much greater than one-twentieth of an inch, with the result that only an extremely hard crust or skin on the manganese steel object is formed which is underlaid by very soft steel, for example around 200 Brinell, which may flow and become deformed or distorted in response to heavy pressure or heavy sustained impact applied, resulting in distortion of the metal structure which supports the hardened surface and cracking of this hardened surface to such an extent as to make the manganese casting unusable.

It is an object of the invention to provide methods of hardening manganese steel wherein selected surface portions of the manganese steel casting or other object are subjected to the direct force and shock waves resulting from the explosion of an explosive material disposed in predetermined proximity to the surface of the portion which has been selected for hardening but usually in actual contact with the selected surface. Among the advantages resulting from the use of the methods herein-

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after disclosed are that the hardness, degree of hardness and the graduation of the hardness from extremely hard at the surface through ranges of decreasing hardness to a condition of low hardness at a point within the manganese steel object may be obtained; the method may be performed in a comparatively short time and without use of expensive and cumbersome equipment such as required by the workhardening methods now employed; and the results of the hardening methods are predictable so that consistency of results are the rule rather than the exception.

An amount of control can be exercised over these methods which makes unnecessary highly skilled labor for handling the methods and consequently the results do not depend upon the human equation to the extent that prevails with the known conventional methods of work hardening manganese steel.

More specifically, it is an object of the invention to provide a method of work-hardening manganese steel wherein a quantity of explosive is placed contiguous to the surface of the portion of the object of manganese steel selected for hardening, and is then detonated so that the surface and underlying portion of the metal are subjected to extremely high shocks of short duration involving pressures of the order of a million pounds per square inch. The shock waves produced within the steel as a result of the explosive attack are attended by lattice distortion and molecular readjustment of the steel structure during the progress of the shock waves until the resultant pressures therefrom are so reduced that no significant further lattice distortion or molecular adjustment occurs. This lattice distortion of the metal structure and molecular readjustment result in an increase of hardness which is proportional to the shock wave pressures applied and as the lattice distortions diminish in depth, so the degree of hardness is correspondingly reduced in depth. The final result, therefore, of attacking the surface of manganese steel with explosives as herein-after explained is to cause a maximum hardness increase at or very near the surface of the manganese steel and a gradual decrease of the hardness increment with depth. By use of the methods hereinafter set forth, significant increases in hardness can be produced within a manganese steel casting to a depth of the order of ten or more times as great as with shotpeening. This depth hardening is predictable by control of the explosive forces applied to the manganese steel object and can be varied as desired.

It is a further object of the invention to provide a method of hardening manganese steel wherein a layer of explosive material is placed upon a selected surface area of the manganese steel object which is to be hardened and exploded.

A further object of the invention is to provide a method of hardening manganese steel wherein at least a portion of the manganese steel object and the explosive material are covered with a substance heavier than air.

A further object of the invention is to provide a method of hardening manganese steel objects wherein at least a portion of the object and the hardening explosive are submerged in a substance which is heavier than air.

A further object of the invention is to provide a sheet of explosive material which may be readily cut, bent and formed so as to conform to the surface configuration and dimensions of the portion of the manganese steel object which is to be hardened and wherein a sheet of the explosive material, so formed is placed contiguous to the surface of the manganese steel object and exploded.

A still further object of the invention is to provide a method of hardening manganese steel objects wherein the object to be hardened is subjected to an explosive force or forces selectively applied to said object or a portion thereof, with the object to be hardened resting upon or placed against another object of suitable resiliency and of other characteristics such as lead and other similar materials.

Another object of the invention is to subject a manganese steel object a plurality of times to explosive shocks or pressure waves in order to produce with each separate explosion an increase in hardening effects as well as depth of hardening under the surface of the object being work-

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hardened to which an explosive material has been applied and detonated.

It is a further object of this invention to maintain at a minimum the total impulses received by each unit area of surface being treated while at the same time maintaining a maximum shock loading pressure. This may be effected by using a thin sheet of explosive of the order of $\frac{1}{8}$ of an inch in thickness for those castings whose structure is fairly light, or possessing, in other words, a small cross section. The use of a massive layer of explosive while undoubtedly producing hardness effects in considerable depths, would also produce structural distortion and deformations and very probably render the casting completely unusable. Stated differently, by maintaining a high detonation pressure to propagate the necessary shock waves but by selectively controlling the amount of total explosive impulse applied per unit area, there will be employed the depth hardening properties which are an intrinsic part of the progress of such high intensity shock waves into the manganese steel without the adverse effects which would result from maintaining explosive pressures over a longer period of time and thereby producing conditions of impulse which would damage the structure as a whole. With this invention, we control, therefore, the explosive loading of the surface of the object being work-hardened. A heavy attack by explosive would maintain a thrust of approximately one million pounds per square inch over a sufficiently long period of time actually to deform the object to a point where such object would be unusable. There would be, therefore, in such massive explosive attack two conditions. First, the immediate entry into the steel of a shock wave as a result of detonation of the explosive and, two, the application of pressures over a period of time which is dependent upon the amount of explosive utilized in proximity to any particular area.

A still further object of the invention is to provide a method of hardening manganese steel objects whereby physical deformation or distortion of the objects is reduced to a minimum.

Still another object of this invention is to use a confining vehicle or medium such as water or other fluid for both the object being work-hardened and the explosive in order that the confining effect of water or such fluid may maintain the pressure of the explosive agent against the manganese steel surface and at the same time support the structure as a whole in order to reduce the possibility of distortion as a result of the explosive impulse and in order to inhibit the production of sound which might otherwise make the use of this invention objectionable in certain populated areas.

A still further object of this invention would be to introduce between the surface of the manganese steel object being work-hardened and the explosive sheet a layer of a modifying material such as lead, wax or other similar substance, wherever it is desirable to control the hardening effect of the steel object as to both surface and depth hardening and it is a further object of the invention to taper or graduate this intermediate layer in thickness so that the explosive and hardening effects are controlled and varied as desired in selected portions or areas of the object.

Further objects and advantages of the invention will be brought out in the following part of the specification wherein I have described preferred embodiments of the invention in detail so as to make a complete disclosure of the invention without, however, limiting the scope of the invention defined in the appended claims.

Referring to the drawings which are for illustrative purposes only:

Fig. 1 is a schematic view showing the manner in which the explosive wave front acts upon a piece of manganese steel or other work-hardenable metal or alloy, this view also including a graph showing the gradual hardening of the metal to a depth within the metal piece.

Fig. 2 is a fragmentary perspective view showing a portion of a shovel tooth with a thin layer of explosive material placed on two opposite sides of its point portion for the purpose of pre-hardening this point portion.

Fig. 3 is a quarter-sectional view of a conical bowl liner of a crusher, showing a sheet of explosive material applied to the working surface thereof.

Fig. 4 is a perspective view showing a cylindrical shell for a mill roll with a layer of explosive applied to the surface in preparation for the hardening of the shell,

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this view also showing the manner in which the steel object and the explosive are submerged in a fluid which is heavier than air.

Fig. 5 is a schematic view showing another method of covering a selected portion of a manganese steel object and the explosive which is to harden a selected portion thereof.

Fig. 6 is a plan view of a portion of a manganese steel railway crossing casting, with strips of explosive placed thereon.

Fig. 7 is an enlarged fragmentary sectional view taken as indicated by the line 7—7 of Fig. 6.

In Fig. 1, for the purpose of illustrating the invention in simple form, I show a piece 3 of manganese steel, the upper portion of which is to be hardened. Upon the upper surface 4 of the piece 3 I place a layer 5 of high-powered detonating explosive. This layer 5 of explosive may be made as a sheet and the thickness thereof is approximately $\frac{1}{8}$ inch. The sheet of explosive 5 is exploded by use of a detonator 6 which is connected to a laterally projecting portion of the explosive sheet. The result of this is that the progress of the detonation is from left to right across the surface 4 of the piece 3 as indicated by the arrow 7. Accordingly, as the detonation wave front moves from left to right as indicated by the line 8, a shock wave 9 will move from left to right through or within the piece 3 in following relation to the wave front 8. The hardening effect, due to the diminishing intensity of the shock wave within the piece 3, diminishes gradually downwardly from the surface 4 within the piece 3 as indicated by the curve 9 of the graph which forms the rightward portion of Fig. 1. At the surface 4 there is accomplished a hardness of about 400 Brinell or in some instances in excess thereof. Instead of an abrupt reduction in hardness below the hardened surface portion, the hardness reduces gradually, the ordinary heat-treat hardness of 200 Brinell being encountered nearly one inch below the surface 4 of the piece 3.

In Fig. 2, I show a portion of a digger tooth 10 such as is employed in earth and rock handling equipment, for example, scoop shovels, ditch diggers, etc., cast or otherwise formed from manganese steel. It is desirable to have the point of the tooth 10 hard and wear resistant, with the remainder of the tooth sufficiently soft to withstand heavy load and shock without breaking. To harden the point 11 of the tooth 10 a layer 12 of explosive material is placed on two opposing surfaces thereof. The explosive material of the layer 12 may be an explosive material such as PETN (penta-erythritol tetranitrate) which is made in the form of a sheet which may be cut to shape with shears or other tools and molded or bent to conform to the surface of the manganese steel object to be treated. A tongue 13 projects from the upper portion of the sheet of explosive material to which a detonator may be attached. The layer 12 of explosive material may be exploded in the open air, with the result that the point of the tooth 10 is subjected to explosively engendered shock or pressure waves. After the explosion of the layer 12, another layer of explosive material may be placed on the point 10 and exploded so as to increase the depth of the hardening effect. This second layer of explosive material may be decreased in vertical dimension so that only the extreme point of the tooth 10 will receive the additional hardening effect resulting from its being exploded.

In Fig. 3, I show a portion of a conical bowl 14 of manganese steel such as employed in cone type rock crushers. To the working surface 15 of the manganese steel bowl a layer of explosive material 16 is applied. The working surface 15 of the bowl 14 is contoured, that is to say that it has surface areas which extend in angular relation to other surface areas so that shoulders are formed. The layer 16 of explosive material is molded so as to conform to the contour of the surface 15, and when this layer of explosive material is exploded it will accomplish a hardening of the entire working surface 15 to which it has been applied, the hardening effect extending into the metal a distance which depends upon several factors, including the thickness of the layer 16 and the power of the explosive material from which this layer 16 is formed.

In Fig. 4, I show a cylindrical roll shell of manganese steel such as employed in rolling mills. The heavy and concentrated pressure applied to the surface of rolls of this type causes the metal of the roll to flow laterally

with the result of flanging of the ends of the rolls. A sheet 18 of explosive material is applied to the surface of the manganese steel roll 17 and both the explosive sheet 18 and the roll 17 are covered by submerging them in a substance which will restrain or confine the explosive force to a greater extent than will the open air. The roll 17 and the layer 18 of explosive material is shown covered by or submerged in material 19 which may be water or other liquid, sand or metal particles. The submerging or covering material 19 may be any granular or liquid substance. The layer 18 of explosive is shown with an extending tab 21 to which a detonator 22 may be attached, this detonator 22 being of the electrically ignited type provided with extending conductors 23 and adapted to be connected to an igniting circuit.

In Fig. 5, I show another method of covering at least a part of the explosive layer and the article which is to be hardened. Herein I have shown a supporting jig 25 on which an article 26 of manganese steel of any desired configuration is supported by a layer 27 of yieldable material, such as lead, rubber, plastic, fibre, etc. A modifying layer 28 of a selected material is placed over the portion of the article 26 which is to be hardened. A sheet of explosive material 29 is placed over the modifying layer and a cover member 30 is disposed over the layer 29 of explosive material, this cover member 30 comprising a manganese casting 31 supported by guides 32 for vertical movement. When the layer 29 of explosive material is exploded, the cover member 30 may yield upwardly, so that neither it nor the article 26 will be ruptured. To protect the cover member 30 a layer 33 of yieldable material is disposed between the lower end of the cover member 30 and the layer 29 of explosive material. The modifying layer 28 and the protective layer 33 are made of a material softer or of greater yieldability than the steel of the article 26 or the steel of the cover member 30. Either or both of the explosive layer and the modifying layer are selectively varied in thickness to control the hardening effect in different areas. I have shown the explosive layer 29 modulated in thickness so as to control both surface and depth hardening of different portions of the article 26.

In Fig. 6, I show the upper surface of a manganese steel railway crossing casting 35 having flangeways 36 and 36' formed in part by wheel treads 37 and 38 disposed in crossing relation so that at the point 39 where the flangeways 36 and 36' cross there are corners 40, 41 and 42 across which the car wheels travel. In order to harden the wheel treads 37 and 38 strips of explosive material are placed thereon and exploded in sequence as will be hereinafter explained, portions 47 of these strips of explosive material being extended down over the side faces 48 of the wheel treads 37 and 38 defining side walls of the flangeways 36. When the explosive strips are exploded the upper faces of the wheel treads 37 and 38, the side faces 48 thereof, and the metal lying thereunder are hardened consistently throughout their lengths.

A strip 43 of explosive material is placed upon the wheel tread 37 as shown in Figs. 6 and 7, and by use of a detonator 44 at one end thereof is exploded, hardening the upper face of the wheel tread 37 and also the lateral face 48 thereof. The corners 41 and 42 will be hardened since they are portions of the tread 37. A similar strip 43' of explosive material, as indicated by dotted lines in Fig. 6, is placed on the wheel tread 38, crossing the flangeway 36 and traversing the corner 41. This strip 43' is then exploded, hardening the wheel tread 38 and subjecting the corner 41 to a second shock wave treatment so as to increase the depth of hardness in the metal lying below the corner 41 and also increasing the surface hardness of the corner 41. The hardness of any selected portion of the part treated may be increased by consecutive explosive or shock wave treatment applied thereto. It has been explained in the foregoing how the hardness of the corner 41 has been in-

creased. Other of the corners such as the corners 40 and 42 may be increased in hardness by subsequent explosion of layers of explosive material thereon.

I claim:

1. A method of hardening at least a portion of an article of austenitic manganese steel which comprises placing contiguous to the surface of the portion of said article to be hardened a sheet of explosive material conforming approximately to the configuration of said surface, exploding said explosive material such that at least a portion of the shock wave thereby produced will enter said surface and effect hardening of said steel in substantial depth, said hardening diminishing progressively from said surface of said steel inwardly, the quantity of said explosive material being sufficient to harden said steel in substantial depth below said surface but less than that which will permanently deform the surface contour of said article more than a negligible amount.

2. The process of claim 1 wherein said surface of said portion of said article and said sheet of explosive material are covered with a substance heavier than air prior to exploding said explosive material.

3. The process of claim 2 wherein said surface of said portion of said article and said sheet of explosive material are submerged in said substance.

4. The process of claim 3 wherein said substance is water.

5. The process of claim 1 wherein said sheet of explosive material is selectively varied in thickness to effect varying degrees of hardening in pre-selected areas of said surface.

6. The process of claim 1 wherein said sheet of explosive material is approximately one-eighth inch in thickness.

7. The process of claim 1 wherein said explosive material is penta-erythritol tetranitrate.

8. The process of claim 1 wherein a layer of modifying material is placed between said sheet of explosive and said surface to modify the force of the explosion of said explosive material.

9. The process of claim 8 wherein said layer of modifying material is selectively varied in thickness to control the hardening effect of said explosive in pre-selected areas of said surface.

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