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METAL SURFACE CONDITIONING APPARATUS AND PROCESS

Original Filed June 10, 1944

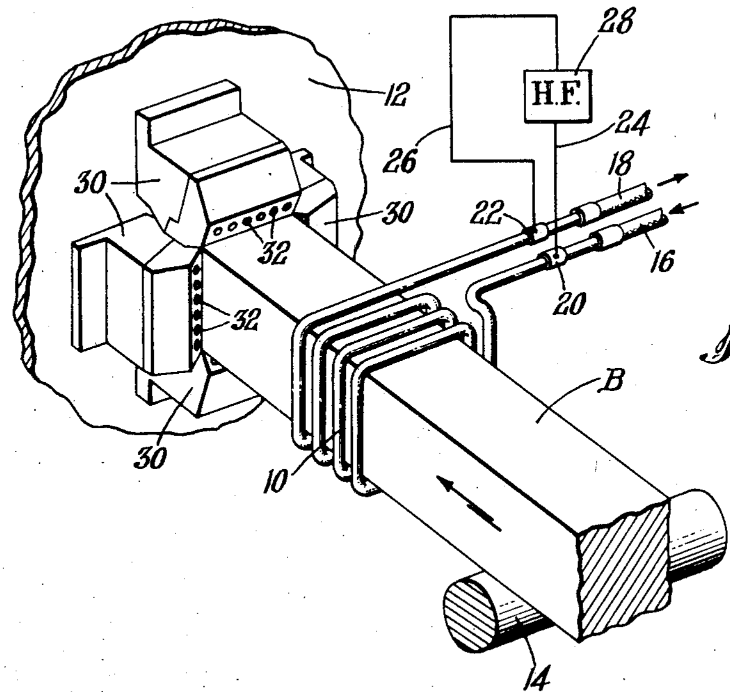

Fig. 1.

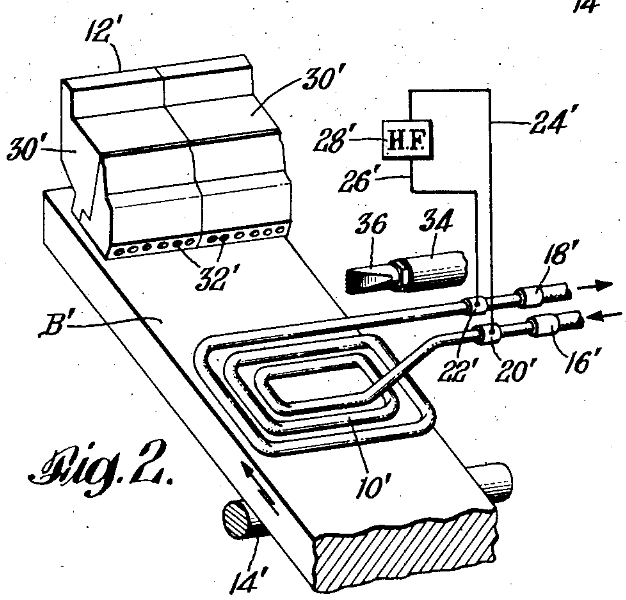

Fig. 2.

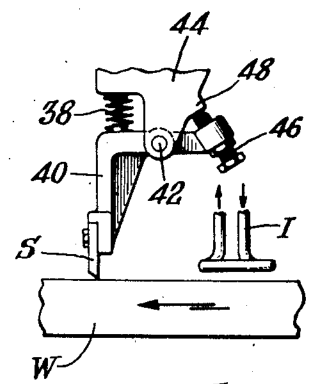

Fig. 3.

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METAL SURFACE CONDITIONING APPARATUS AND PROCESS

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7 Claims. (Cl. 219—1)

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This invention relates to the art of conditioning the surfaces of metal bodies, and more particularly to an improved method of and apparatus for removing defects or scale from the surfaces of metal bodies.

This application is a division of my application Serial No. 539,664, filed June 10, 1944, for "Metal surface conditioning apparatus and process," now abandoned.

Metal bodies, particularly hot-rolled metal shapes, are conditioned in various ways to improve the surfaces. When metal bodies are heated and hot worked, they become coated with scale. Also metal bodies which are produced from cast ingots often have other surface defects such as small cracks, seams, and slag inclusions that cannot be removed by rolling and which would appear as defects in the finished products. Usually at some stage of manufacture, it is necessary that such defects be removed by surface conditioning before the metal is further worked. Several methods of conditioning are employed. For example, defective surface metal may be removed by machining, such as chipping with a chisel or milling. This is either relatively slow and tedious if done by hand, or requires very expensive and massive machinery of high first cost and high maintenance charges. For non-ferrous metals no other method is generally practiced. In steel mills, however, the combustibility of iron in oxygen permits the extensive use of oxy-acetylene desurfacing machines which remove both scale and a layer of surface metal by action of a row of oxygen jets against the surface while it is at an ignition temperature.

Although the desurfacing reaction on steel generates enough heat so that, after ignition is initially obtained, the reaction can, under certain favorable conditions, be continued along the metal surface without any auxiliary source of heat, it is, in practice, necessary that an auxiliary source of heat be supplied for the reason that the reaction with oxygen alone is relatively unstable and quite inefficient in the use of the gas. Thus it is customary to supply added heat by providing gas heating flames such as oxy-acetylene flames adjacent the oxygen jets. These flames greatly increase the efficiency of surface metal removal and stabilize the reaction. These flames are also used before the oxygen is applied initially to heat a portion of the metal to an ignition temperature. Oxygen and acetylene are generally used although sometimes a different fuel gas may be employed, but in the latter case a much larger amount of oxygen is required.

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Therefore, there is, in either event, a large gas consumption expense for the heating flames.

Steel conditioning machines using oxygen and heating flames are often set into the rolling mill line. Such machine may remove from each body a thin layer containing surface defects from 1, 2 or 4 sides continuously, and the operation is performed while the metal of the body is still hot and without interrupting the rolling operation. Secondary conditioning, i. e., the removal of deeper defects, if such should be necessary, is sometimes performed by hand deseaming after the steel body has cooled down to room temperature.

The necessity of supplying gases for the preheating or heating flames causes considerable complication of the apparatus and involves difficulties of control and supply of the additional gas, and also the expense of maintaining the flame producing means, which maintenance would be much reduced if oxygen jets alone are employed. Not all metals are combustible with oxygen and to condition bodies of such metals it has been proposed to melt the defective surface metal sufficiently to cause the cracks to fuse together, such melting being accomplished by the progressive application of high temperature flames or electric arcs. The heat transmission or transfer between flames and surface metal or between arcs and surface metal is relatively poor so that these methods are expensive in the consumption of gas or electric power. The descaling of metals by the application of high temperature concentrated flames to local areas in order to expand the scale and cause it to break loose from the metal surface, also requires the use of expensive gases.

Therefore, the main objects of this invention are to provide a novel and improved method of and means for conditioning metal bodies; improved means for heating the surface of a ferrous metal body for starting and maintaining a thermochemical desurfacing operation on the body with oxygen; an improved method of removing surface defects and scale from metal bodies; desurfacing or deseaming apparatus which is simple and economical to manufacture and maintain, which is efficient and effective in operation, and which effects a saving in removed metal; a process of and apparatus for conditioning a metal body to eliminate defects and scale which is more efficient in use of energy and which either eliminates entirely or reduces substantially the consumption of valuable gas; an improved process of and apparatus for conditioning non-ferrous metal bodies to eliminate surface defects such as cracks; and an improved process of and apparatus for loosening or removing scale from metal bodies.

According to an embodiment of the invention particularly adapted for desurfacing steel bodies, high-frequency induction heating of the work to be desurfaced is employed in conjunction with the use of a stream of oxidizing gas containing at least a core of commercially pure oxygen in order to reduce or avoid entirely the use of preheating fuel gas, such as acetylene and the oxygen required to burn such gas. For example, a surface portion of a ferrous metal body to be desurfaced is first heated to ignition temperature with high-frequency waves from a suitable source, such as an inductor or capacitor. The induced current and resulting heat are localized, by control of the frequency, to the skin of the body which may be already at the rolling temperature of the metal, or cold. When the skin of the metal body reaches the ignition temperature with oxygen, characteristic oxidizing gas streams are applied to such preheated skin and the surface of the latter is thermochemically removed by movement of the preheating source and oxidizing streams with respect to the body undergoing treatment.

The depth of the inductively preheated skin of the metal body may be varied or adjusted by changing the frequency of the waves induced in such skin, and the locally heated area may be predetermined with any suitable arrangement of the inductor coils or unit with respect to the surface of the skin. For example, a single loop inductor which conforms substantially to the shape of the body being treated may surround such body in order progressively to preheat a peripheral zone which is thereupon thermochemically removed by oxidizing gas streams which are directed against such preheated peripheral zone, the body being moved in the direction of the axis of the inductor loop to progressively desurface such body in a single pass. Alternatively, one or more suitable inductors may be used to preheat one or more of the faces of the body, or a portion of one face.

According to an aspect of the invention, metal bodies having defects such as small surface cracks, and especially metals that do not react readily with oxygen, are conditioned to eliminate such defects by high-frequency induction heating alone. An inductor is arranged adjacent each surface to be conditioned and the body and inductor are moved relatively to each other so as to treat the entire surface. The high-frequency current intensity is sufficient to cause local fusion of the surface metal, especially in the region of the defects so that the defects become eliminated by the flowing together of the metal. The slag inclusions flood to the surface so that a smooth uniform surface layer of metal results. The frequency is regulated or predetermined so that the melting occurs only to the depth desired. Solidification of the fused surface metal takes place rapidly after the surface area moves away from the influence of the inductor due to the flow of heat from the molten surface into the interior of the metal body.

Sometimes it will be desirable mechanically to remove the heat-softened surface metal and in such instances a scraper having a blade of highly heat resistant metal may be pressed or urged against the moving body surface immediately following the inductor.

The above described processes may be carried out while the body is cold, but are more economically performed while the body is hot and passing from one hot working operation to another. The treatment, in addition to conditioning the body, also adds heat to the body so that a step of furnace heating the body between hot working operations which is often required can be eliminated.

According to still another aspect of the invention, scale may be removed from cold metal bodies. The scale that accumulates on metal bodies due to heating them in a furnace or to exposure to the atmosphere while they are hot usually adheres very tenaciously after the body has cooled. Such scale can be loosened by the progressive local application of concentrated high-intensity heat which causes differential expansion to occur between the scale layer and the surface of the metal, and causes the scale to break loose from the surface. According to the invention, such scale is removed economically by the application of high-frequency induction heat. Such heat is created in the scale layer along a narrow area of the surface by an inductor carrying high-intensity current of relatively high-frequency and the inductor and metal body are moved relatively with respect to each other to treat the entire surface to be descaled. The frequency of the heating current is selected to confine the heating entirely in the scale layer so that only the scale is effectively heated, which causes it to expand and fly away from the metal surface.

In the drawing:

Fig. 1 is a fragmentary perspective view of apparatus exemplifying the invention;

Fig. 2 is a similar view of a modification of the invention; and

Fig. 3 is a view in side elevation of another modification.

Referring to Fig. 1, a high-frequency skin preheater 10 and an oxygen desurfacing unit 12 are arranged in rolling mill line, including a conveyor 14, to first inductively heat the skin of a ferrous metal body B and then thermochemically remove or scarf such preheated surface from the body as the latter is moved along such line by the conveyor 14. The high-frequency skin preheater 10 preferably comprises an inductor which encircles the body B, such inductor consisting of a pipe composed of electrically conductive material, such as copper or graphite, through which a cooling fluid, such as water, is circulated from a suitable source, through inlet and outlet connections 16 and 18. The coil 10 may, if desired, be made adjustable to accommodate a body of any cross-sectional size or shape, by being formed of telescoped tubes which permit the coil to be expanded or contracted about the body. Terminals 20 and 22 of the induction heating unit 10 are connected by conductors 24 and 26 to the output circuit of a source 28 of high-frequency alternating current, such as an electronic oscillator, for example. The power of source 28 is sufficiently high to cause the electro-magnetic field of the inductor 10 to induce a current of sufficient intensity in the skin or surface layer of the body B, as the latter is moved by the conveyor therethrough, to raise the temperature of such surface until the skin metal becomes at least hot enough for ignition with streams of oxygen discharged from the desurfacing unit 12.

Through the use of such high-frequency current the induction heating is confined to the skin or external surface layer of the body B. The depth of heating is controlled by the frequency, the amount of power induced in the surface of the body, and the rate of relative movement between the induction coil 10 and the body B. Since the body B is already at a rolling temperature, and moving at a rate of the order of 135′ per minute, for example, the arrangement is such that the temperature of the skin on all four surfaces of the body B is raised to an ignition value, preferably molten, as the preheated surfaces are moved into the thermochemical reaction zone of the desurfacing unit 12.

The desurfacing unit 12 preferably comprises a plurality of heads 30, there being a head corresponding to each of the four sides of the body B. The heads 30 also may, if desired, be made so that they may be adjusted to accommodate a body B of any cross-sectional shape or size. Each head 30 includes a plurality of desurfacing nozzles 32, each of which is provided with an orifice for discharging a characteristic stream of commercially pure oxygen at an acute angle against the adjacent surface or side of the body as the latter is moved through the unit 12. Oxygen at a suitable pressure is supplied to each of the nozzles 32 in use during the desurfacing operation.

In operation, the body B is moved by the conveyor 14 first through the alternating electromagnetic field of high-frequency and high power, within the induction heater 10, inducing heat in the surface metal of the body until it reaches at least the ignition temperature, and then through the zone of the inclined streams of oxidizing gas discharged by the nozzles 32 of the heads 30 of the desurfacing unit 12, which impinge against the work surface at an acute angle and thermochemically remove the inductively heated surface metal from the body B. In this way surface defects are entirely removed from all sides of the ferrous metal body B.

Referring to Fig. 2, there is illustrated a modification for removing surface defects from the top only of a ferrous metal slab B′ as the latter is advanced by a conveyor 14′. The slab B′, which may be already at a rolling temperature, is moved by the conveyor directly under the induction heating unit 10′ in the form of a pancake coil comprising a plurality of turns of copper or graphite tubing having terminal portions 20′ and 22′ provided with cooling fluid inlet and outlet connections 16′ and 18′, such terminal portions being also connected in the output circuit of a high-frequency power source 28′ by conductors 24′ and 26′.

The coil 10′ may be provided with a suitable core, not shown, for the purpose of concentrating the magnetic flux and the heating current thereby induced in the slab B′, so that intense heat is generated and concentrated in a limited portion of the upper surface of the slab B′ as the latter is moved toward the desurfacing unit 12′ consisting of a pair of heads 30′, including oxygen discharging nozzles 32′. In this modification there is provided a water supply pipe 34 which terminates in a nozzle 36 for discharging a flat stream of water above and across the top surface of the slab B′ and in edgewise relation thereto, to continuously deflect and remove slag resulting from the desurfacing operation, the water stream discharged by the nozzle 36 being positioned so as to protect the induction coil 10′ from the thermochemical reaction and from the products of combustion and slag. In this manner the coil 10′ can be positioned close to the nozzle heads 30′.

In operation, the slab B′ is moved by the conveyor 14′ in the electro-magnetic field of the high-frequency coil 10′, inducing current in the surface of the slab which heats the skin for ignition with oxygen. Streams of oxygen discharged by the nozzles 32′ of the desurfacing unit 12′ thermochemically combine with and remove the metal at ignition temperature from the surface as the conveyor 14′ continues to advance the slab B′ under the unit 12′. The slag resulting from the thermochemical desurfacing operation is projected forwardly of the unit 12′ along the surface of the slab toward the coil 10′. During this operation the stream of water discharged by the nozzle 36 continuously removes slag from such surface and protects the coil 10′ from the intense heat and from such slag.

In Fig. 3 the work W is caused to move directly under an induction heating unit I and then under a mechanical scraper S which is urged or pressed into contact with the surface of the work by a spring 38, the scraper being carried by an arm 40 which is pivoted at 42 to a support 44. Downward movement of the scraper S is limited by a stop screw 46 threaded through the opposite end of the arm 40 for engagement with a shoulder 48 on the support 44. In operation the inductively heated and softened or molten skin of the work W is scraped therefrom by the scraper S as the work is moved thereunder.

According to the invention, surface scale or a layer of predetermined thickness, depending upon the frequency selected, is heated to the desired temperature by means of a high-frequency source of electricity to eliminate surface defects. If such induction heating treatment is sufficient to remove the defects, such step is all that is necessary. However, the invention also includes removing all or only a portion of such heated layer while it is molten or soft by mechanical means, such as a scraper (as shown in Fig. 3) or toothed milling wheel, or by a fluid or gas blast, or thermochemically with oxidizing gas such as an oxygen stream (as shown in Figs. 1 and 2). Since the thickness of the surface layer or skin which is heated by induction is a function of the frequency of the source of electricity, automatic control of the depth of the surface layer of metal which is removed from the body is accomplished by increasing or decreasing such frequency.

In desurfacing with oxygen, according to the invention, it will be understood that an alternating current of high-frequency may be induced in a surface zone of a steel body, for example, to heat the metal of such zone to an ignition temperature for thermochemical reaction with oxygen. A stream of oxygen is then applied against the heated metal in such zone at an acute angle to the surface of the body. Successive zones are similarly heated along a predetermined path to be deseamed on the surface of the body, and the stream of oxygen is advanced along such path and directed obliquely against such heated zones, so that the heated metal is progressively removed.

In addition to controlling the depth of a conditioning operation, a distinct advantage of the invention arises by virtue of the fact that a defect in the surface of a metal body is caused to heat more readily than the sound metal because of the skin-effect of the high-frequency current induced in the metal body, the current being urged to flow in a surface layer of predetermined depth. When conditioning by fusion alone, the higher resistance to induced currents caused by the defect, heats the defect to a higher temperature so that the defective metal ignites and fuses more readily than the sound metal. Also when desurfacing with oxygen, the resistance of the defect to the flow of induced current causes the latter to attain a higher temperature and thereafter to ignite and react or burn, more easily than the solid surface metal when the oxygen is applied. Thus, when a stream of oxygen is subsequently applied to the inductively preheated surface metal, the glowing defects, being hotter than the surrounding metal, are removed more completely by thermochemical reaction with the oxygen. A saving of metal is effected because the entire surface need not be removed to the full depth of the deepest defects. The oxygen stream removes metal to a greater depth wherever the temperature of the metal is higher, thus only a very thin layer of sound metal need be removed while the defective metal in the region of the defects which may be considerably deeper is also automatically removed.

In descaling work according to the invention, the metal body and the induction heater are moved relatively with respect to each other, with the heater as close as possible to the surface to be descaled, either manually or by mechanized means. The frequency of the current induced in the scale is such that it heats rapidly and flies away from the work surface, leaving the latter clean and free of objectionable scale.

What is claimed is:

1. The method of surface conditioning a metal body which comprises heating the skin of said body by high-frequency current induced therein, and mechanically removing the so-heated skin from the body with a scraper.

2. The method of machining metal to shape through the use of a cutting tool wherein the metal and the tool move relative to each other, which method consists in applying localized heating to the metal by the use of a high-frequency induction coil, and then cutting away the portion so heated with the cutting tool before the heat is able to travel substantially to other parts of the metal.

3. The method of machining metal to shape which consists in the steps of applying progressive, localized heating by the use of a high-frequency induction coil to the area to be removed, and progressively removing the metal so heated by the use of a cutting tool which changes position relative to the work.

4. In the art of machining metal by the use of a work handler and cutting tool associated therewith, the method which consists in applying localized heating to that portion of the work to be removed in advance of the cutting operation, the localized heating being applied by the use of a high-frequency induction coil which progressively raises the temperature in such areas to a temperature below the melting point of the metal, and then removing the metal by the cutting tool before the heat is substantially conducted to areas not being removed.

5. The method of eliminating defects in the skin of a metal body which comprises inducing current in such skin to heat and soften the metal in the zone of a defect, and then mechanically removing such heated metal while the latter is still soft.

6. In the art of surface conditioning metal by the use of a surface layer remover, the method which consists in applying surface layer heating to a surface portion of the work in advance of the surface layer removing operation, the surface layer heating being applied by the use of a high-frequency induction coil which progressively raises the temperature in such surface layer to a temperature which renders the metal more easily removable by said remover, and then progressively removing the so heated metal with said surface layer remover before the heat is substantially conducted to adjacent areas.

7. Metal surface conditioning apparatus comprising, in combination, a high-frequency induction coil for heating a surface layer of the work by high-frequency induction so as to soften only such surface layer with respect to the underlying metal, and means for scarfing only the so heated and softened surface layer from the work while such layer is still hot and soft and the underlying metal is hard and thereby offers a limit to the depth of the metal removed.

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