June 19, 1962 P. A. OELGOETZ 3,039,950

APPARATUS FOR ELECTRO-CHEMICALLY REMOVING METAL

Filed May 15, 1959 2 Sheets-Sheet 1

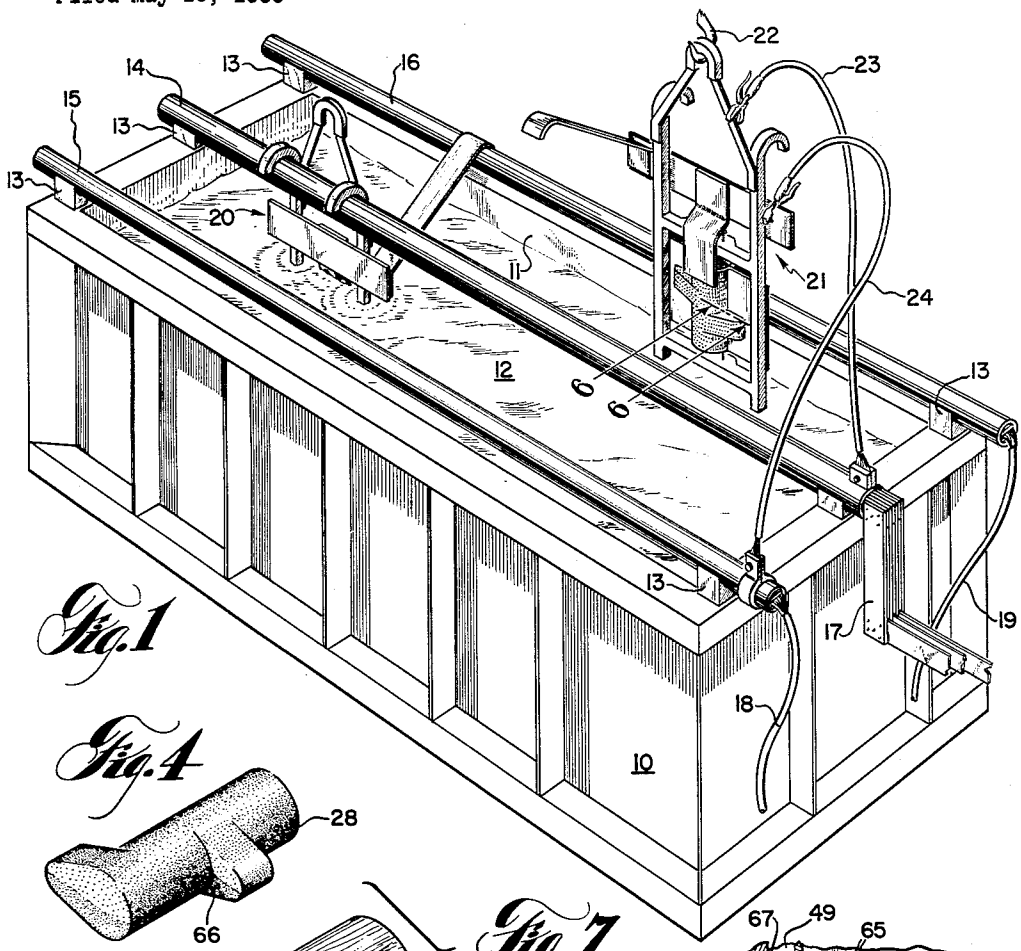
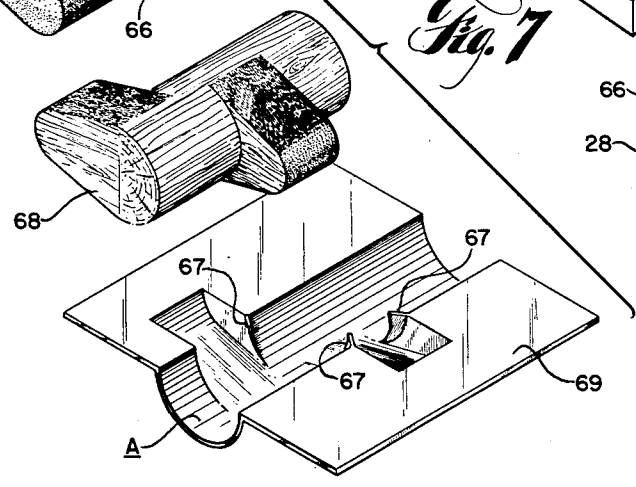



Fig. 1

Fig. 4




Fig. 7



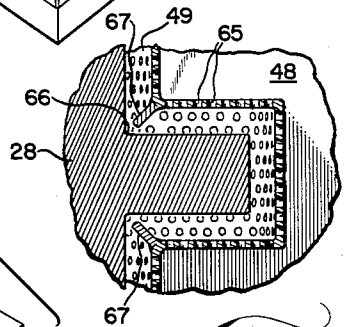




Fig. 6

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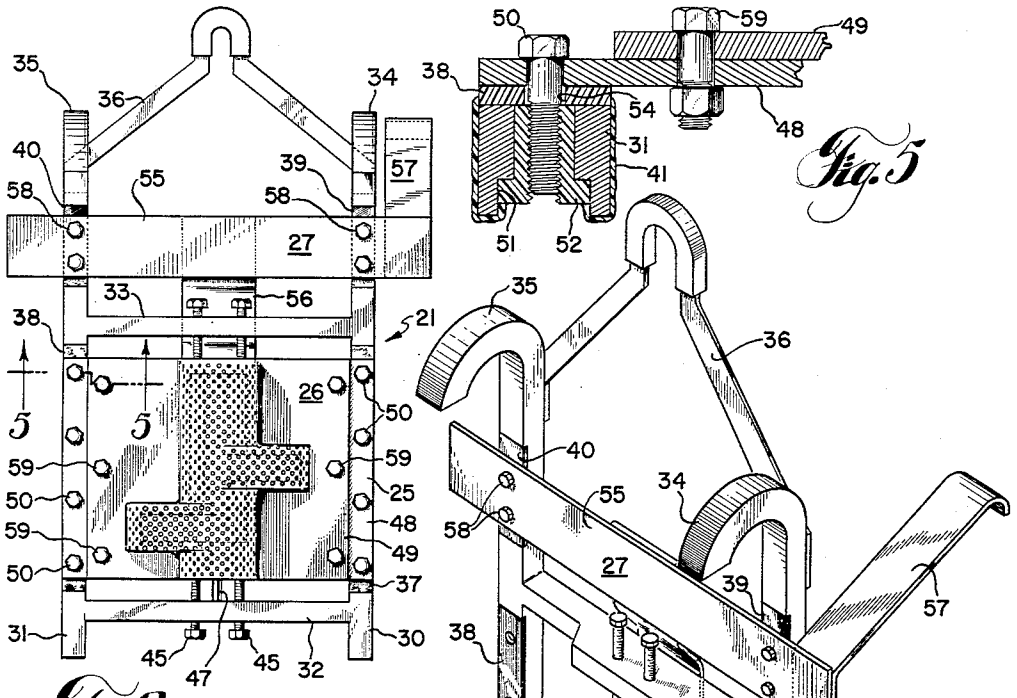



Fig. 2




Fig. 5




Fig. 3

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United States Patent Office 3,039,950 Patented June 19, 1962



3,039,950

# APPARATUS FOR ELECTRO-CHEMICALLY REMOVING METAL

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Filed May 15, 1959, Ser. No. 813,558
5 Claims. (Cl. 204—242)

This invention relates generally to apparatus for electro-chemically removing metal, and is concerned with an improved equipment arrangement for use in removing metal from a contoured workpiece immersed anodically in an electrolyte.

Also, this application is a continuation-in-part of my co-pending application for Letters Patent Serial No. 733,-291, filed May 6, 1958, and now abandoned.

It is an important object of this invention to provide apparatus for removing metal from contoured workpieces fabricated of ultra-high-strength steel and like materials.

Another object of this invention is to provide improved apparatus for uniformly removing metal electro-chemically from the exterior surfaces of a contoured workpiece.

Another object of this invention is to provide an equipment arrangement effective to remove metal from contoured ultra-high-strength steel workpieces having substantial surface fillet areas provided therein.

Another object of my invention is to provide apparatus which effects improved electrolyte circulation in connection with the uniform electro-chemical removal of metal from immersed contoured workpieces.

A still further object of this invention is to provide a comparatively inexpensive equipment arrangement for electro-chemically removing metal from contoured workpieces.

Another object of this invention is to provide electro-chemical metal removing apparatus which may be operated economically.

A still further object of this invention is to provide a tooling arrangement which may be readily maintained in connection with an electro-chemical metal removal technique developed for contoured ultra-high-strength steel workpieces.

Other objects and advantages of this invention will become apparent during consideration of the specification and drawings.

In the drawings:

FIG. 1 illustrates an electro-chemical metal removal equipment arrangement incorporating the features of this invention;

FIG. 2 is an elevational view of an equipment tooling assembly portion illustrated in FIG. 1;

FIG. 3 is an exploded illustration of the tooling assembly shown in FIG. 2;

FIG. 4 is another view of the workpiece shown in FIG. 3;

FIG. 5 is a sectional view taken at line 5—5 of FIG. 2;

FIG. 6 is a partial sectional view taken at 6—6 in FIG. 1; and

FIG. 7 illustrates a pattern and an overlay intermediate used in connection with the fabrication of the overlay means illustrated in FIG. 3.

The equipment arrangement illustrated in FIG. 1 includes a tank 10 having an acid-resistant lining 11 and having an acid bath 12 contained therein. Supported by the edges of tank 10 and by insulating block members 13 carried thereon are anode bus bar 14 and cathode bus bars 15 and 16. Bus bar 14 is electrically connected to the anode (positive) terminal of a direct current electrical energy source by the conductor means 17. Cable means 18 and 19 are provided to electrically connect cathode bus bars 15 and 16 respectively to the cathode (negative) terminal of the same direct current electrical energy source.



The equipment arrangement of FIG. 1 also includes tooling assemblies 20 and 21. Assembly 20 is partially immersed in bath 12 in its operating condition, and is supported by and electrically connected to bus bars 14 and 16. Tooling assembly 21 is illustrated suspended above path 12 prior to partial immersion therein and is supported by the overhead hoist means 22. In the FIG. 1 illustration, assembly 21 is electrically connected to the aforesaid direct current electrical energy source through conductor means 17, bus bar 14, and temporary conductor 23, and through cable means 18, bus bar 15, and temporary conductor 24. Assembly 21 is shown in reversed relation to partially immersed assembly 20. For discussion purposes, further details are provided with respect to tooling assembly 21. Such details are equally pertinent to the tooling assembly designated 20.

Referring to FIGS. 2 and 3, tooling assembly 21 includes frame member 25, overlay means 26, and conductor means 27 which electrically connects overlay means 26 to cathode bus bar 15 when the assembly is positioned in bath 12. Assembly 21 contains the workpiece 28 (FIG. 3) which is to have metal uniformly removed from the surface thereof by the equipment described herein.

Frame member 25 is comprised of vertical bars 30 and 31 and transverse bars 32 and 33 connected thereto. The upper portion of each bar 30 and 31 is formed to provide the conductor portions 34 and 35 which electrically connect frame member 25 to anode bus bar 14 when the assembly is positioned in the electrolyte bath 12. Support 36 is connected to the upper portion of vertical bars 30 and 31 for use in raising and lowering assembly 21 into the bath. If desired, support 36 may be used as a temporary electrical conductor for connecting conductor 23 thereto as shown in FIG. 1. Insulating strips 37 and 38 are acid-resistant and are provided in recessed portions of bar members 30 and 31 to electrically insulate overlay means 26 therefrom when the tooling components are assembled. Likewise, insulating strips 39 and 40 are acid-resistant and are provided in recesses in the upper portion of vertical bars 30 and 31 to electrically insulate conductor means 27 therefrom when it is secured to the assembly for support. I prefer to fabricate frame member 25 and the metal components attached thereto of aluminum or an alloy thereof. Further, the exposed exterior portion of frame member 25 below conductor portions 34 and 35 is coated with an acid-resistant organic film 41. The presence of the frame coating is illustrated in the detail section of FIG. 5.

Contoured workpiece 28 is connected to frame member 25 by threaded fastener means 45 prior to the removal of surface metal from the workpiece. Each fastener means 45 cooperates with a threaded opening provided in transverse bar 32 or transverse bar 33 and is arranged so that the illustrated pointed end portion thereof engages a corresponding opening 46 provided at an end of workpiece 28. In an alternate arrangement, workpiece 28 can be provided with boss portions (not shown) for receiving openings 46 if the presence of such openings within the surface of the end product is objectionable. Such boss portions would be removed by a machine tool or the like after surface metal has been removed from the contoured workpiece electro-chemically. Stud 47, which cooperates with a locating hole provided in workpiece 28, is attached to transverse bar 32 for locating and supporting workpiece 28 while it is being assembled to frame member 25. Fastener means 45 and stud 47 serve to electrically connect workpiece 28 to anode bus bar 14 through frame member 25.

In order that workpiece 28 might have excess metal

uniformly removed therefrom electro-chemically, tooling assembly 21 is provided with the overlay means designated generally by the number 26. Overlay means 26 is comprised of fixed overlay 48 and removable overlay 49 electrically connected thereto. Details regarding the contoured portion A of each overlay and the relation of each contoured portion A to workpiece 28 will be provided hereinafter.

Fastener means 50 connect fixed overlay 48 to frame member 25 in supporting relation only. Frame member 25 is provided with several counterbored openings such as 51 for receiving the shouldered and threaded insulating inserts 52 (see FIG. 5). Each fastener means 50 passes through an opening 53 provided in fixed overlay 48 through an opening 54 provided in either insulating strip 37 or insulating strip 38 and is threadably engaged with an insulating insert 52.

Overlay means 26 is electrically connected to a cathode bus bar through the previously-mentioned conductor means 27. Such conductor means is comprised of transverse bus strip 55, depending bus strip 56, and conductor member 57. Strip 56 is electrically connected to strip 55 and to fixed overlay means 48. Conductor member 57 is likewise electrically connected to transverse bus strip 55 and engages cathode bus bar 15 when assembly 21 is immersed in electrolyte 12. For purposes of rigidity, transverse bus strip 55 is secured to the upper portion of frame member 25 by the various fastener means 58. Each fastener means 58 may be secured to the upper portion of either vertical bar 30 or vertical bar 31 in the same manner as fastener means 50 is secured to the lower portion of frame member 25.

Overlay means 26 is completed by fastening removable overlay portion 49 to fixed overlay portion 48. Such is accomplished through fastener means 59 which pass through openings 60 in overlay 49 and through openings 61 in overlay 48. Details regarding this particular connection are illustrated in FIG. 5.

Referring to FIG. 3, overlays 48 and 49 are provided with a contoured portion A and with essentially flat portions extending to either side therefrom. Such flat portions contact each other when overlays 48 and 49 are combined to form overlay means 26. When workpiece 28 is properly installed in completed tool assembly 21, contoured portions A are arranged to be uniformly distant from the exterior surfaces of the workpiece. In connection with the specific equipment installation described hereinafter, by way of example, it is preferred that the interior surfaces of contoured portions A be uniformly located approximately ¾" from the corresponding exterior surfaces of workpiece 28.

Overlays 48 and 49 are fabricated of cast aluminum alloy and, by way of example, are preferably ¼" thick. Perforations 65 are provided in each contoured portion A and are preferably ¼" in diameter and spaced in staggered rows at approximately ⅝" on centers. Such perforations improve the uniformity of metal removal from the exterior surfaces of workpieces 28. Such perforations are also conducive to improved circulation of etchant 12.

Workpiece 28 is illustrated as having fillet areas 66 (FIG. 4 and FIG. 6). In order that uniformity of metal removal might be extended to such areas, I prefer that overlay means 26 be provided with the projection elements designated 67. Such elements are electrically connected to overlay 48 and overlay 49 and, by way of example, project to within ¼" of the fillet root area. Elements 67, which are of an aluminum alloy or the like, may be secured to the overlay by a welding technique. For the best illustration of the installed projection elements 67, refer to overlay 48 of FIG. 3 and to FIG. 6.

By way of additional illustration, FIG. 7 shows a master pattern 68 which is made oversize with respect to workpiece 28. Pattern 68, which is ¾" oversize in the preferred arrangement, may be utilized in a conventional mold-making technique to produce a mold for casting the overlay intermediate 69. Intermediate 69 is provided with perforations 65 and projection elements 67 to create the completed overlay 48.

The apparatus described above is particularly useful to remove metal from workpieces fabricated of alloyed steels having ultra-high tensile strengths when heat treated. Such materials are typically heat treated to a tensile strength in the range of from 260,000 p.s.i. to 300,000 p.s.i. Their typical composition by percentage of total weight is given as follows:

| Element | Steel "A" | Steel "B" | Steel "C" |
|---|---|---|---|
| Carbon | 0.33–0.38 | 0.48–0.53 | 0.38–0.43 |
| Manganese | 0.25–0.40 | 0.25–0.40 | 0.20–0.40 |
| Phosphorus | 0.025 max. | 0.025 max. | 0.025 max. |
| Sulphur | 0.025 max. | 0.025 max. | 0.025 max. |
| Silicon | 1.00–1.20 | 1.00–1.20 | 0.80–1.00 |
| Chromium | 4.75–5.25 | 4.75–5.25 | 4.75–5.25 |
| Molybdenum | 1.25–1.50 | 1.25–1.50 | 1.20–1.40 |
| Vanadium | 0.35–0.55 | 0.85–1.15 | 0.40–0.60 |
| Nickel | | 1.35–1.65 | |
| Iron | Remainder | Remainder | Remainder |
| Total | 100 | 100 | 100 |

The above-described steels are difficult to machine using conventional machine tools and are susceptible to hydrogen embrittlement if such metal is removed by an acid or if parts made thereof are electro-chemically etched under cathodic conditions. Considerable difficulty has also been encountered in removing decarburized surface metal from exterior areas of forgings or other heat treated parts made of the above steels. Thus, the apparatus of this invention is particularly useful to remove surface metal from workpiece 28 if the workpiece is fabricated of an ultra-high-strength alloy steel and if it has been forged to shape using a conventional hot forging technique.

Further, by way of example, in connection with the removal of surface metal from a hot forged ultra-high-strength steel workpiece 28 it is satisfactory that electrolyte 12 be a water solution of a single acid. For instance, an acid solution containing from 20% to 30% of sulfuric acid by weight is suitable. Such solution should be air agitated during the use of the apparatus of this invention and should be preferably maintained at a temperature of from 70° F. to 90° F.

The heretofore-mentioned direct current electrical energy source should preferably have a capacity to provide an operating potential of from 9 volts to 40 volts. Such equipment should also be capable of providing a current flow intensity of from 5 amperes per square inch to approximately 13 amperes per square inch, each based upon the total exterior surface area of the workpiece 28 being treated.

It is to be understood that the form of the invention herewith shown and described is to be taken as the preferred embodiment of the same, but that various changes in the shape, size, and arrangement of parts may be resorted to without departing from the spirit of the invention or the scope of the subjoined claims.

I claim:

1. Apparatus for uniformly removing metal from a contoured workpiece and immersed in an acid electrolyte, comprising: anode frame means, fastener means fixedly and electrically connecting said workpiece to said frame means, cathode overlay means having a contoured portion which envelops said workpiece and which is provided with a contour that corresponds substantially to the complete contour of said workpiece, and second fastener means fixedly connecting said overlay means to said frame means in electrically insulated relation, said overlay means contoured portion being spaced-apart from corresponding exterior surface areas of said workpiece to a uniform distance whereby metal is uniformly removed from substantially the complete contour of said workpiece when direct current electrical energy is flowed

from said cathode overlay means to said anode frame means as said cathode overlay means, workpiece, and anode frame means are held in fixed relation.

2. Apparatus for uniformly removing metal from over substantially the entire suface of a shaped workpiece, and comprising: tank means containing an acid etchant, anode bus bar means connected to a direct current electrical energy source, cathode bus bar means connected to said electrical energy source, frame means having said workpiece electrically and fixedly connected thereto and supported thereby, overlay means having a contoured portion which is provided with a shape congruent to the shape of said workpiece, which is located in fixed and non-moving relation to all surface portions of said shaped workpiece, and which is uniformly spaced-apart from said workpiece in substantially complete surrounding relation, and conductor means connecting said overlay means to said cathode bus bar means said frame means being electrically connected to said anode bus bar means when said workpiece is immersed in said acid etchant.

3. Apparatus for uniformly removing metal from a contoured workpiece and immersed in an acid electrolyte, comprising: anode frame means, fastener means electrically connecting said workpiece to said frame means, cathode overlay means having a projecting auxiliary cathode portion and having a contoured portion which envelops said workpiece and which is similar to the contour of said workpiece, and second fastener means connecting said overlay means to said frame means in electrically insulated relation, said auxiliary cathode portion being electrically connected to said overlay means contoured portion and projected into a fillet region of said workpiece, and said overlay means contoured portion being spaced-apart from corresponding exterior surface areas of said workpiece to a uniform distance whereby metal is uniformly removed from said workpiece when direct current electrical energy is flowed through said cathode overlay means, workpiece, and anode frame means.

4. Apparatus for uniformly removing metal from the surface of a shaped workpiece, and comprising: tank means containing an acid etchant, anode bus bar means connected to a direct current electrical energy source, cathode bus bar means connected to said electrical energy source, frame means having said workpiece electrically connected thereto and supported thereby, overlay means having a projection element electrically connected thereto and having a contoured portion substantially completely surrounding said workpiece which is provided with a shape similar to the shape of said workpiece and which is uniformly spaced-apart from said workpiece, and conductor means connecting said overlay means to said cathode bus bar means, said projection element being located on an interior surface of said overlay means and projected into a fillet area of said workpiece, and said frame means being electrically connected to said anode bus bar means when said workpiece is immersed in said etchant.

5. In an equipment arrangement for electro-chemically removing metal to a uniform depth from the exterior surface of a contoured workpiece, in combination: anodic frame means, fastener means electrically connecting said workpiece to said anodic frame means in supported relation, cathodic overlay means surrounding said workpiece and having a perforated contoured portion provided with an oversize contour of said workpiece and having a projection element electrically connected to the interior surface thereof, and fastener means connecting said cathodic overlay means in fixed relation to said workpiece, said projection element being extended from the interior surface of said overlay means a sufficient distance to provide for uniform metal removal from a fillet area located in said workpiece adjacent said projection element.

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