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3,408,237

DUCTILE CASE-HARDENED STEELS

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Fig. 1

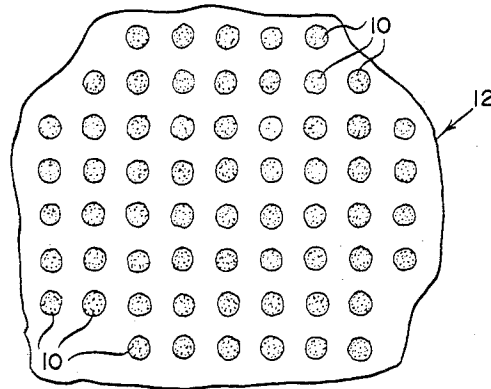


Fig. 2

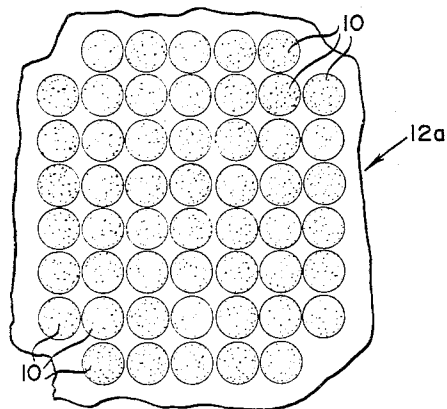
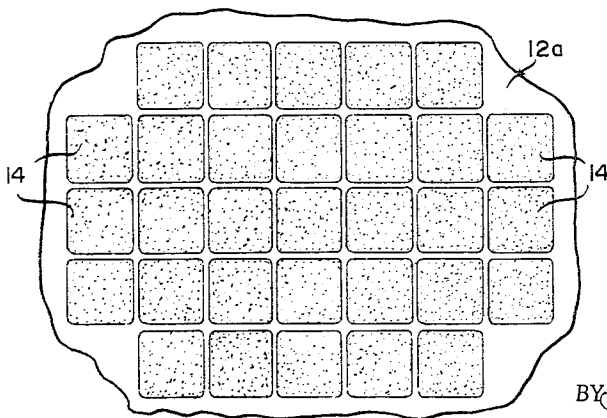


Fig. 3

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DUCTILE CASE-HARDENED STEELS

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Continuation-in-part of application Ser. No. 379,139, June 30, 1964. This application Mar. 16, 1967, Ser. No. 633,651

2 Claims. (Cl. 148—15.5)

ABSTRACT OF THE DISCLOSURE

Steel materials having discontinuous case-hardened areas surrounded by continuous ductile areas, materials having series of very small case-hardened areas and materials fabricated from ductile case-hardenable steels having over surface regions thereof a case-hardened pattern imparting to that surface the hardness and wear characteristic of case-hardened steel and the bending and ductility characteristics of unhardened ductile steel are described herein.

This is a continuation-in-part of application Ser. No. 379,139, having a similar title and filed by the same inventors on June 30, 1964, now abandoned. It has been known heretofore to selectively case harden soft steel so as to facilitate the working and fabrication of such steel. So far as is known, the prior art has not yet developed a discontinuous case-hardened pattern over a large area, or all, of one or more surfaces of a fabricated ductile case-hardenable steel material, such as fabricated carburizing and nitriding carbon-containing steels, so as to make optimum use of the ductility, of the wear resistance, and of other attributes of case-hardened steels.

Selective case hardening which is known in the prior art has resulted in steel plates incapable of being further worked or has required precision in leaving areas to be worked unhardened. The present invention, on the other hand, discloses a method of mass producing case-hardened material which may be worked and bent at all points.

It is an object of this invention to provide hardware, sheet material, and like fabricated materials having both a hard wearing surface and ductility.

More particularly, it is an object of this invention to provide a case-hardened patterned surface on a carbon-containing case-hardenable steel part which is highly resistant to wear and yet retains enough ductility to allow bending, forming, straightening or the like without detrimental effects on the part, such as induced cracking or impairment of its wearing characteristics.

More specifically still, it is an object of this invention to provide an over-all pattern of case-hardened wearing surfaces on hardware parts and other materials fabricated from normally soft and ductile low carbon and nitriding steels without sacrificing ductility.

It is a special object of this invention to provide a process for producing a desired over-all substantially uniform pattern of unhardened and case-hardened regions on a soft, ductile fabricated carbon-containing steel material which is case-hardenable by carburizing, nitriding, or the like.

It is another special object of the invention to provide fabricated ductile case-hardenable steel materials having a raised pattern of discontinuous case-hardened steel in a continuous matrix of the unhardened material.

It is yet another special object of the invention to pro-

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vide an over-all pattern of unhardened and case-hardened regions on a surface of a fabricated case-hardenable steel in which the case-hardened regions occupy the major portion of the surface. It is a still further special object of the invention to provide an over-all uniform case-hardened pattern of microminiature spots on the surface of ductile steel parts.

The foregoing and other objects, features and advantages of the invention will become apparent from the more detailed description of special embodiments of the invention as illustrated in the accompanying drawings.

FIGURE 1 is a reproduction of a photomicrograph of a portion of a substantially uniform pattern of carburized case-hardened spots on a plate of carburizing steel, prior to the removal of a copper maskant, in which the holes in the maskant have an average diameter of about 0.005" and an average distance of 0.015" from center-to-center.

FIGURE 2 is a diagrammatic representation of FIGURE 1 after the removal of the maskant showing a carburized case, which is about 0.002" thick, and illustrating the lateral spread of the case-hardened areas.

FIGURE 3 is a diagrammatic representation similar to FIGURE 2 with the lateral distance from center-to-center being twice that of FIGURES 1 and 2, and in which case-hardened carburized discontinuous spots are substantially square in shape and occupy a decidedly predominant proportion of the surface of the sheet.

Broadly viewed, the objectives of the invention are obtained by first outlining a pattern of continuous and discontinuous regions over at least one surface of a fabricated ductile case-hardenable steel material, by covering a part only of the surface of the material with a maskant which inhibits or prohibits case hardening, leaving uncovered the pattern to be case hardened, then case hardening the uncovered pattern, and thereafter removing the maskant to leave a pattern of case-hardened and unhardened regions.

Known methods of case hardening may be used including carburizing, nitriding, cyaniding, carbonitriding, and the like. Carburizing, or carbonitriding and nitriding are preferred. Flame and induction hardening are also applicable, providing a pattern of continuous and discontinuous regions over the surface of a fabricated material is first case carburized.

In the case hardening of the sheet illustrated in FIGURE 1, copper was used for the known purpose of the stopping-off of carburizing on a fabricated sheet of AISI C-1010 carbon steel, which is known to be well adapted for carburizing. First, the sheet was thoroughly cleaned, and then it was dipped in a photoresist. A negative pattern being opaque to the monochromatic light used, and having therein holes corresponding to carburized dots 10, described below, was placed over one side of the sheet and the pattern was exposed to monochromatic light for a period of time sufficient to fix a pattern of dots corresponding to the holes in the negative pattern. Then the pattern of dots was developed in a developer solution, and the unexposed photoresist was removed in the usual manner, leaving only the developed dots having a radius of about 0.005". Next, after cleaning in a known way, the sheet was immersed in an electrolytic copper plating bath to electrodeposit a continuous layer of copper all over one side of the sheet and a continuous region of copper 12 surrounding the developed dots on the other side of the sheet. After 50 minutes' residence in the bath, and under the conditions set out below, a copper plating 0.7 mil thick was deposited.

Plating bath and plating conditions

Copper cyanide	-----oz./gal.	6
Potassium cyanide	-----oz./gal.	9.7
Potassium hydroxide	-----oz./gal.	1.0
Sodium potassium tartrate	-----percent by vol.	6
Bright copper makeup	-----do.	2
Temperature	-----° F.	130
Current density	-----amps.	20-25
Cathode rod agitation	-----ft./min.	20

After the copper was deposited, the developed dots were removed in a known way to provide a copper coated sheet of the carburizing ductile carbon steel with a pattern of holes corresponding to dots 10 on one surface thereof. Upon immersing the copper clad sheet in a typical cyaniding bath, set out below, for 25 minutes at 1450° F., carburizing to a depth of about 0.002" took place, and a case-hardened surface was obtained after quenching in oil in a known manner.

Cyaniding bath

	Percent
Sodium chloride	-----25
Sodium cyanide	-----50
Barium carbonate	-----25

After the case hardening was obtained, the copper was stripped from the sheet in a known way in a chromic acid strip bath. Upon removal of the copper, it was apparent the carbon had penetrated laterally as well as downwardly so that the carburized dots 10 had the dimensions shown in FIGURE 2.

Desired variations in the extent and depth of the carburized regions can be obtained by varying the period of treatment or the temperature of the bath or both.

By using a negative pattern having uniformly distributed holes with a diameter of 0.010" and centers 0.015" apart, a pattern of carburized dots 10 occupying about 60% of the total working surface is obtained. The dots are surrounded by a continuous pattern of unmodified sheet material 12a as diagrammatically represented in FIGURE 2. As shown in FIGURE 3, when it is desired to carburize even larger proportions of the surface of the fabricated material, a negative pattern may be used provided with square or other rectilinear holes corresponding to the carburized case-hardened waffle design 14. These larger case-hardened designs, having unhardened channels therein, afford an excellent means for supplying surface lubricants.

It is obvious the techniques set out above may be used to develop a pattern of case-hardened regions over as many, or as much, of the surfaces of the fabricated material as may be desired.

It is apparent also, the same techniques set out above may be used for case hardening by nitriding known nitriding grades of carbon-containing alloy steels as, for example, ASTM A-355, class A. As is known, such steels preferably contain a small percentage of aluminum or chromium to facilitate nitriding. In such a process the material, or parts, may be heated in an atmosphere of ammonia gas and dissociated ammonia mixed in suitable proportions, or in contact with a nitrogenous medium. The process is carried out below the transformation range for the steel used, and no quenching operations are necessary. A suitable nitriding cycle is carried out at a temperature of 950-1050° F. The flow of ammonia is adjusted so as to maintain a concentration of 70 percent ammonia and 30 percent nitrogen and hydrogen in the exhaust gas.

As used herein "microminiature" has the conventional definition of very small. Where microminiature regions of case hardening are not advantageous, or necessary, as often is the case, other means of carburizing may be used as, for example, covering desired regions with carbonaceous cements and then heating to carburizing temperatures and thereafter quenching. Also, where larger

case-hardened areas are desired, the copper may be electrodeposited by using other types of maskant during the electrodeposition of the copper on the fabricated material, such as paints or waxes, to mask the electrodeposition of the copper.

Where it is desirable to have uniform wear properties and/or uniform ductility, it is necessary to have a uniform pattern of case-hardened and unhardened regions over the surface of the fabricated material. It is apparent, however, that the principles of this invention may be used to provide irregular patterns of hardened and unhardened regions over the surface of the material.

The advantages of this invention are obtained by having patterns of ductile steel over the surface of a case-hardened object, whereby the object may be bent at all points for the construction of a case-hardened part. When patterns of case-hardened and unhardened areas are uniform, case hardening may be carried out in mass production without regard for the particular area of a blank to be bent.

The optimum advantages of this invention are obtained for most applications where a substantially uniform discontinuous pattern of case-hardened miniature dots is provided surrounded by a continuous pattern of unhardened ductile material. In this way, optimum ductility is retained while permitting the development over very large proportions of the fabricated material very hard and wear resistant patterned regions. The minimum size of the dots is limited only by the available "art work" or maskants. In general, the illustrative embodiments shown herein, wherein the radius of the hole in the maskant is 0.005" and the centers are 0.015" apart, represent about the minimum practical size for carburizing for the process it most advantageously practiced when the carburized regions do not merge. Since carburizing to a depth of 0.002" usually is desirable, if not necessary, it will be apparent the carburizing regions will merge when carburizing through such a copper mask to a depth substantially exceeding 0.002". For the purposes of this invention the most useful case-hardened dots may be considered dots with a maximum dimension of 0.100". Uniformly distributed case-hardened dots having a radius between 0.005 and 0.010" are preferred where uniformity, ductility and formability are desired together with hardness and wear resistance. In many applications dots having a diameter of 0.050" are quite small enough.

It will be understood, of course, the principles of this invention may be used to develop case-hardened patterns having desired dimensions even exceeding 0.100". For instance, where lubrication is a more important objective and ductility is of less importance, case-hardened patterns having case-hardened regions with dimensions greatly exceeding 0.100" may prove quite satisfactory.

Thus fabricated materials having surface patterns of case-hardened and unhardened regions over a surface thereof, as described above, have a number of advantages over like fabricated materials now readily available, including:

(1) Flat parts can be roller straightened, where hand straightening has heretofore been considered necessary.

(2) Forming operations are possible which are not possible with an over-all hardened case.

(3) Microminiature case-hardened regions of high density are made available.

(4) Less expensive ductile carbon steels can be used where more expensive case-hardened steels have heretofore been considered necessary.

(5) When the discontinuous regions are carburized to form elevated case-hardened regions, the continuous regions form excellent lubrication channels; and, where case-hardened regions are not raised, the unhardened regions wear in and may also serve as lubricating regions, or for like purposes.

While the invention has been particularly shown and described with reference to a preferred embodiment

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thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A case-hardened steel product comprising a partially case-hardened portion having at least one face defining a plurality of isolated uniformly distributed case-hardened areas having maximum surface dimensions of from approximately 0.005 to 0.010 inch, and having centers of such areas spaced approximately 0.015 inch apart.

2. The process for producing a partially case-hardened steel product having at least one face defining a plurality of isolated case hardened areas comprising:

cleaning at least one face of a steel blank;
coating the at least one face with a photoresist;
exposing discontinuous regions of the photoresist coating with a predetermined pattern of radiant energy;
washing away unexposed portions of the photoresist coating, leaving a continuous bare area of the at least one face;

electrodepositing a copper coating on the bare area of the at least one face;

removing exposed areas of the photoresist coating, thereby exposing predetermined discontinuous portions of the at least one face of the blank, said dis-

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continuous portions having maximum surface dimensions of from approximately 0.005 to 0.010 inch, and having centers of such areas spaced approximately 0.015 inch apart;

case-hardening discontinuous exposed portions of the face; and

removing the copper coating, thereby providing a product having discontinuous case-hardened regions and continuous unhardened regions.

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CHARLES N. LOVELL, *Primary Examiner*.