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ELECTROLYTIC POLISHING AND REMOVING EXCESS METAL

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The present invention relates to a method of reducing the dimensions of over-size articles to predetermined dimensions.

In the manufacture of metal articles that must have exact dimensions, machining to size generally constitutes the last stage in the production operations. This final machining to size requires a disproportionately long time and is correspondingly expensive.

The present invention provides a means for treating metal articles having over-size dimensions to produce metal articles having exact predetermined dimensions.

It is an object of the present invention to provide a process for removing metal by dissolution from metal articles to provide a metal article having predetermined dimensions within the tolerances generally accepted by the art.

It is another object of the present invention to provide a process for producing metal articles having exact predetermined dimensions within generally accepted tolerances wherein an over-size article is subjected to anodic dissolution sufficient to remove excess metal and provide a metal article having predetermined dimensions.

It is a further object of the present invention to provide a process for producing metal articles having predetermined dimensions wherein an over-size metal article is intermittently subjected to anodic dissolution and intermittently subjected to attrition or abrasion to produce a metal article having predetermined dimensions.

The present invention also contemplates the use of anodic dissolution which may or may not be accompanied by abrasive treatment as intermediate stages in the processing of metals to desired shapes.

Other objects and advantages of the present invention will become apparent from the following description:

In the production of all but a few types of metal articles having exact dimensions which must be held within certain generally accepted tolerances, it is usual to bring the article to the predetermined dimensions by a final machining or grinding operation. It is generally recognized that this final machining or grinding operation is disproportionately long and correspondingly expensive.

It has now been discovered that anodic dissolution in a manner somewhat similar to that employed in the electrolytic polishing of metal articles combined with an abrasion step provides a means whereby over-size metal articles can be reduced to exact dimensions in a relatively short period of time and with relatively unskilled labor.

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The step of the present process involving anodic dissolution of the excess metal of the over-size metal articles may be carried out in electrolytes which have been found suitable for the electrolytic polishing of various metals.

However, the present process differs from the electrolytic polishing of metals in many particulars. For example, in the electrolytic polishing of metals, the primary feature of the polishing process is the removal of relatively very little metal. The amount of metal usually removed in an electrolytic polishing operation rarely exceeds a thickness of 0.0001 (1×10^{-4}) inch and only on rare occasions involves the removal of 0.0005 (5×10^{-4}) inch of metal. As a matter of fact, it is the primary objective of the electrolytic polishing process to remove as little metal as is possible commensurate with the production of the type of finish desired.

In distinct contrast to the foregoing, in the present electro-machining of metal articles, the removal of relatively thick layers of metal is required. That is to say, the removal of 0.001 (1×10^{-3}) inch to about 0.003 (3×10^{-3}) inch or even about 0.005 (5×10^{-3}) inch of metal is necessary in order to reduce the dimensions of an over-size article to the exact predetermined dimensions. However, it is well known in the art that the removal of exceptionally thick layers of metal by anodic dissolution from articles composed of nickel and nickel alloys, such as described herein, results in a tendency for localized attacks to develop which lead to pitting, roughening or preferential solution at crystal boundaries. Roughening or preferential solution at the crystal boundaries occurs with great regularity when metals that have been heat-treated under conditions permitting intercrystalline oxidation at the surface are subjected to anodic dissolution.

Of course, those skilled in the art will readily appreciate that a finished article having rough areas and a pitted surface is not acceptable as a finished article, although it may in general have dimensions within the tolerances acceptable for the particular article. Consequently, in view of the well known fact that the removal of layers of metal, which in the electro-polishing art would be considered excessively thick, is accompanied by marked roughening and pitting of the surface, it is surprising that layers of metal of pronounced thickness can be removed by the present process and a finished article having exact predetermined

dimensions and a surface neither roughened nor pitted obtained.

It has been discovered that the roughening and pitting of the surface of the article as a result of anodic dissolution can be substantially eliminated when the anodic dissolution is interrupted and the partially treated article subjected to an abrasive treatment. It would appear that the abrasive treatment stops any preferential attack that may have developed at the surface being subjected to anodic dissolution. Furthermore, by combining the electro-chemical process with the abrasive treatment, it is easy to control the removal of the metal so as to produce exactly the dimensions required by the specifications of the finished article. Preferably, the removal of the major portion of the excess metal is accomplished by anodic dissolution with electrolytes such as are employed in the electrolytic polishing of metals and this treatment provides a metal article having a surface which serves to contrast with any defects, thus aiding in the inspection of the finished product.

The process can be applied to a wide range of the metals and alloys commonly used for engineering purposes and particularly to articles that are forged by die stamping and thus initially have the correct shape and merely require removal of the metal to a uniform depth over the whole surface, such for example as turbine blades. If, however, as is often the case in practice, it is desired to remove a greater amount of metal at one or more parts of the article than at others, this can be effected by various means known to those skilled in the art to proportion the amount of current flowing to a localized area of the anode to the amount of metal to be removed. Thus for example shaped cathodes may be employed. By employing shaped cathodes it is not essential for the article being electro-machined to be any more nearly the correct shape and size than would be the case immediately prior to the final stages of conventional mechanical machining.

While the process may be applied to the electro-machining of articles of different alloy and metal composition, its use has particular advantage in the final reduction to size of metals composed of nickel or nickel alloys, such as 18/8 nickel-chromium steels, nickel-copper alloys such as sold under the trade-mark "Monel," nickel-chromium alloys of the 80/20 type, with or without other modifying elements such as titanium and the like.

Broadly speaking, the present process involves a first step of removing any superficial scale which has not been removed in previous operations. In a second step, the over-size article is immersed as anode in an acid electrolyte such as has heretofore been suggested for the electro-polishing of the particular metal or alloy of which the article is composed. These electrolytes are well known and reference need only be made to a few of the electrolytes known to the art. Thus, for example, suitable electrolytes have been disclosed in the French Patent No. 707,526 and British Patent No. 526,854 and U. S. Patents Nos. 1,658,222, 1,865,470, 1,961,752, 2,145,518, 2,282,350, 2,282,351 and 2,315,696.

The anodic dissolution of the metal of the article is accompanied in many instances by the formation of a sludge or scale and by the formation of pits or fissures along the grain boundaries. When anodic dissolution is allowed to proceed after the formation of pits or fissures of relatively appreciable depth without abrasion, the pits or fissures grow in size and mar the surface of the article. This difficulty can be overcome by reducing the anodic activity of the pits or fissures and in that manner overcoming the tendency to preferential dissolution. A satisfactory method for accomplishing this reduction of preferential solution is shot or sand blasting. The abrasive treatment, such as shot or sand blasting also removes some of the scale or sludge, the formation of which accompanies the anodic dissolution. With some metals and alloys the scale is relatively adherent and can best be removed by shot blasting or sand blasting. In the treatment of other metals, the scale or sludge resulting from the anodic dissolution can be removed by less violent abrasive methods. Thus, for example, the excessive anodic activity or preferential solution of pits or fissures can be eliminated and the sludge produced on some metals and alloys can be removed by means of a revolving fabric-covered wheel carrying an abrasive. Other metals and alloys after anodic treatment are covered with a scale or sludge that is so weakly adherent that it may be removed by wiping or spraying with water jets. The alloy sold under the trade-mark "Monel" is an example of the alloys to which the aforesaid scale or sludge adheres so feebly that it may be removed by spraying with water jets.

It has been found that the most satisfactory results are obtained by subjecting the over-size article to anodic dissolution and abrasive treatment in successive steps in which the over-size article is removed at least once from the electrolyte and subjected to the abrasive treatment. However, most satisfactory results are obtained by subjecting the over-size article to abrasive treatment a plurality of times after the article has first been subjected to anodic dissolution. Thus, for example, when it is desired to remove from about 1×10^{-3} to about 3×10^{-3} inch of metal from the over-size article, most satisfactory results are obtained when the anodic dissolution is interrupted after about one-third of the total amount of metal to be removed has been removed. The article is then subjected to an abrasive treatment to remove the anodic scale or sludge and to reduce the anodic activity of any pits and the like. Then the article is returned to the electrolyte and subjected again to anodic dissolution. The anodic dissolution is interrupted a second time when most, but not quite all, of the excess metal has been removed and the article is again subjected to an abrasive treatment. After this second abrasive treatment, the article is again returned to the electrolyte and the final anodic dissolution of the remainder of the excess metal is obtained.

The amount of metal removed can be determined by weighing the article or can be calculated from a knowledge of the current density employed, the current efficiency, and the time during which the current is applied. Thus, for example, in the removal of metal from 18/8 nickel-chromium steels, nickel-copper alloys such as sold under the trade-mark "Monel", nickel-chromium alloys of the 80/20 type, and the like, in solutions containing 55% by volume phosphoric acid, sp. gr. 1.75, 27% by volume sulfuric acid, sp. gr. 1.84, and the balance water to make 100% by volume, the rate of metal removal is of the order of 10 grams per faraday, i. e. usually between about 30% and 50% current efficiency. Of course the amount of metal removed per faraday will vary with the metal or alloy and with the electrolyte employed.

A wide range of solutions may be employed although it is preferred to employ either a phosphoric acid-sulfuric acid electrolyte or a hydrochloric acid electrolyte. The sulfuric acid electrolyte preferably contains at least 37% by volume phosphoric acid having a specific gravity of 1.75 with the addition of up to 40% by volume of water or without the addition of water, the balance being sulfuric acid. Those skilled in the art will understand that when no additional water is added to the electrolyte, 10% of the phosphoric acid added is water. Accordingly, in a bath containing 37% by volume phosphoric acid, sp. gr. 1.75, and the balance sulfuric acid, sp. gr. 1.84, water is present in the amount of 3.5% by volume, or about 6% by weight.

The preferred electrolyte consists of 55% by volume concentrated phosphoric acid, sp. gr. 1.75, 27% by volume sulfuric acid, sp. gr. 1.84, and the balance water to make 100% by volume. For the phosphoric-acid-sulfuric-acid electrolyte, temperatures up to about 70° C. may be emlpoyed. However, the range is preferably from about 15° C. to about 30° C. The optimum anode current density depends on the type of solution and the metal being treated. For the preferred electrolyte set forth hereinbefore, i. e., 55% phosphoric acid, 27% sulfuric acid, and the balance water, satisfactory results have been obtained employing an anode current density within the range of about 0.5 ampere per square inch to about 30 amperes per square inch, i. e., from about 70 amperes per square foot to about 4500 amperes per square foot. Higher or lower anode current densities may be used, but at higher current densities it is sometimes difficult to maintain the solution within the desired temperature range and at lower current densities the removal of the metal is unduly slow.

The stages at which the electrolytic process is interrupted for abrasive treatment are determined by inspection of the surface or by experience. In electro-machining nickel-chromium alloys of the 80/20 type, typical stages for interruption of the anodic dissolution and abrasive treatment are, after the removal of 7×10^{-4} inch of metal and after the removal of 2×10^{-3} inch of metal.

It will be appreciated by those skilled in the art that frequency of interruption of anodic dissolution will depend, among other things, upon the type of surface ultimately required, just as in the same way in mechanical machining processes it is possible to have rough and smooth machined articles.

While the anodic scale or sludge may be removed and pits and the like conditioned and the article prepared for further anodic dissolution by shot blasting, sand blasting or an abrasive wheel, when serious pitting of the surface has not developed in many instances the sludge or scale can be removed by jets of water. It has been found that relatively adherent scale can usually be removed by shot blasting employing 120-mesh steel shot with an air pressure of 10 lbs. per square inch and a five second time of treatment for an article of 4 square inches in area. However, those skilled in the art will readily appreciate that all of these factors may be varied. Thus, when the scale or sludge is especially adherent as in the case of stainless steels, heavier shot, say of 40-mesh and higher air pressure, for example, 30 lbs. per square inch may be employed for a similar period of time to obtain satisfactory results. On the average, the amount of metal removed by shot blasting

is about 6×10^{-5} inch, although as much as 1×10^{-4} inch of metal may be removed when a severe shot blasting treatment is applied.

The foregoing figures have been calculated on the loss of weight of the article treated. The amount of metal removed at each stage of the shot blasting is approximately the same and is considerably less than the amount of metal removed by the anodic dissolution or the actual electrolytic machining treatment.

In order that those skilled in the art may have a more detailed description of the process the following illustrative example is provided:

Example

An article comprising heat treated material consisting of 20% chromium, 2½% titanium, the balance substantially of nickel, was over-size sufficiently to require the uniform removal of 0.004 (4×10^{-3}) inch of metal from the article. The article was first shot blasted to remove a superficial scale by employing 120-mesh shot at 10 lbs. per square inch pressure for five seconds. The descaled article was then made anode in a bath containing 50% by volume of phosphoric acid, sp. gr. 1.75, 27% by volume of sulfuric acid sp. gr. 1.84, and the balance water. The cathode was a lead sheet. The temperature of the solution was 30° C. and the current density was 1 ampere per square inch (144 amperes per square foot). The total time of treatment was 90 minutes with shot blasting of the same severity as that described hereinbefore, after 15 minutes and after 45 minutes total anodic treatment. The total amount of metal removed when the electrolytic treatment was interrupted for the shot blasting operations was 7×10^{-4} inch and 2×10^{-3} inch, respectively. The appearance, on the surface of the article being treated, of an insoluble black deposit indicated when it was desirable to interrupt the anodic dissolution. The amount of metal removed by shot blasting was 6×10^{-5} inch. At the end of the 90 minute anodic treatment, the article had been reduced to the desired size and the surface was free from pits.

Those skilled in the art will readily appreciate that the process described hereinbefore can be applied readily to the mass production of articles of exact dimension and that, in such an application, the time required to bring the oversize article to the dimensions required by specification can be greatly reduced.

While the present invention has been described primarily in conjunction with the production of articles of predetermined size as a final machining step, it can also be employed as a intermediate step or intermediate steps in the production of articles involving the various conventional processes of forging, milling, machining, turning, etc., with, considerable advantage. Intermediate electro-machining is particularly advantageous in that the electro-machining converts minor surface defects into shallow rounded depressions which are readily filled up on subsequent forging without the formation of laps. Forged articles which are electro-machined as an intermediate operation are much more readily inspected for defects with a saving of about 30% in inspection time in some cases. Such defects as remain can be much more readily removed with as much as a 60% saving in the time spent in the grinding operation. In addition, intermediate electro-machining prior to additional forging reduces the wear on the dies appreciably. Thus,

bar stock may be rough forged in the usual manner to provide a blank. The blank may be then further forged to provide a preformed shape. Electro-machining, following the second forging operation to provide the pre-formed shape, is then employed to provide a surface in which any defects are much more readily recognized and in which the defects can be removed by a grinding operation which is much less extensive and time-consuming than conventional grinding operations. Following the electro-machining, the preformed blank is finished by forging and reduced to the desired size by a second electro-machining operation. Those skilled in the art will understand from the foregoing that metal being shaped may be subjected to one or more intermediate electro-machining operations before being subjected to the final electro-machining operation which provides an article of desired size and having a desired finish. When desirable the electro-machining operation may be employed only as intermediate steps.

Accordingly, although the present invention has been described in conjunction with certain preferred embodiments thereof, those skilled in the art will appreciate that variations and modifications can be made. Such variations and modifications are to be considered within the purview of the specification and the scope of the appended claims. Thus, the coating which appears during anodic dissolution of the over-size article may be termed "anodic scale" or "anodic sludge," regardless of its actual physical appearance.

Similarly, the term "anodic dissolution" has been used in the specification and the claims to indicate that action which takes place at the anode whereby the metal of the anode is eaten away and which may be accompanied by the formation of a sludge or scale which can be readily removed.

Furthermore, it is to be understood that the terms "abrasion" or "abrasive treatment" include any method of removing the anodic scale or anodic sludge involving abrasion or attrition and thereby conditioning the surface of the article to overcome preferential dissolution.

Likewise, the term "conditioning" as used in the appended claims is to be understood to include all operations, such as shot blasting, any abrasive treatment or the like, whereby the article, after being subjected to anodic treatment, is treated to reduce the anodic activity of pits or fissures or the like and, in general, is treated to reduce or overcome preferential solution of localized areas.

In addition, it is to be understood that it is not believed necessary to provide typical examples of suitable electrolytes for all of the metals and alloys which may be treated since satisfactory electrolytes for the electro-polishing of various metals and alloys are known to the art and the broad composition of such electrolytes does not form a part of this invention.

I claim:

1. A process for removing about 0.001 to 0.005 inch of excess metal to dimensionally reduce to predetermined size and electropolish an oversize metal article characterized by intercrystalline oxidation at the surface thereof and made of composition from the group consisting of nickel, nickel-base alloys containing copper, nickel-base alloys containing chromium and stainless steels containing nickel and chromium, which comprises anodically polishing said article in an electrolyte comprising essentially phosphoric acid, sulfuric acid and water, the combined concentration of said acids being at least about 50% by weight of said electrolyte, until about one-third of said excess metal is removed, abrading the anodically polished surface by impact of abrasive particles on said surface to decrease the anodic activity of said surface in a succeeding anodic polishing treatment, repeating the said anodic polishing and abrasion treatments, and subjecting said article to a final anodic polishing treatment whereby by said successive in-order step series of anodic polishing treatment and abrasion treatment and said final anodic polishing treatment said article is reduced to desired dimensions and electropolished.

2. A process for removing about 0.001 to 0.005 inch of excess metal to dimensionally reduce to predetermined size and electropolish an oversize metal article comprising about 20% chromium and the balance substantially all nickel, said article being characterized by intercrystalline oxidation at the surface thereof which comprises shot blasting the metal article to remove superficial scale, anodically polishing the descaled article in an electrolyte containing about 50% by volume of phosphoric acid specific gravity 1.75, 27% by volume of sulfuric acid specific gravity 1.84 and the balance water, until about one-third of said excess metal is removed, abrading the anodically polished surface by impact of abrasive particles on said surface to decrease the tendency for preferential corrosion in a succeeding anodic polishing treatment of said surface, repeating said anodic polishing and abrasion treatments, and subjecting said article to a final anodic polishing treatment to reduce said article to desired dimensions.

3. A process for removing about 0.004 inch of excess metal to dimensionally reduce to predetermined size and electropolish an oversize metal article comprising about 20% chromium, about 2.5% titanium, and the balance substantially all nickel, said article being characterized by intercrystalline oxidation at the surface thereof, which comprises shot blasting the metal article and to obtain a descaled article, immersing the descaled article as anode in an electrolyte containing about 50% by volume of phosphoric acid specific gravity 1.75, 27% by volume of sulfuric acid specific gravity 1.84 and the balance water, passing an electric current through said electrolyte at an anode current density of about 144 amperes per square foot for about 15 minutes, abrading the anodically treated surface by impact of abrasive particles upon said surface to decrease the tendency for preferential corrosion in succeeding anodic treatments of said surface, immersing said article in said electrolyte as anode and passing electric current of the aforesaid current density therethrough for about 30 minutes, again abrading said article, and again subjecting said article to anodic dissolution for about 45 minutes whereby said excess metal is removed and an electropolished article reduced to desired dimensions is obtained.

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