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SHOT PEEN INSPECTION TECHNIQUE

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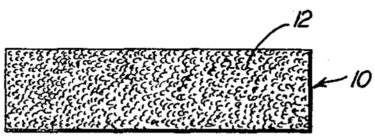

FIG. 1.

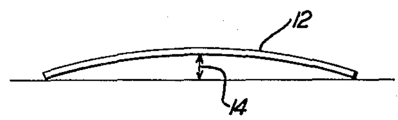

FIG. 2.

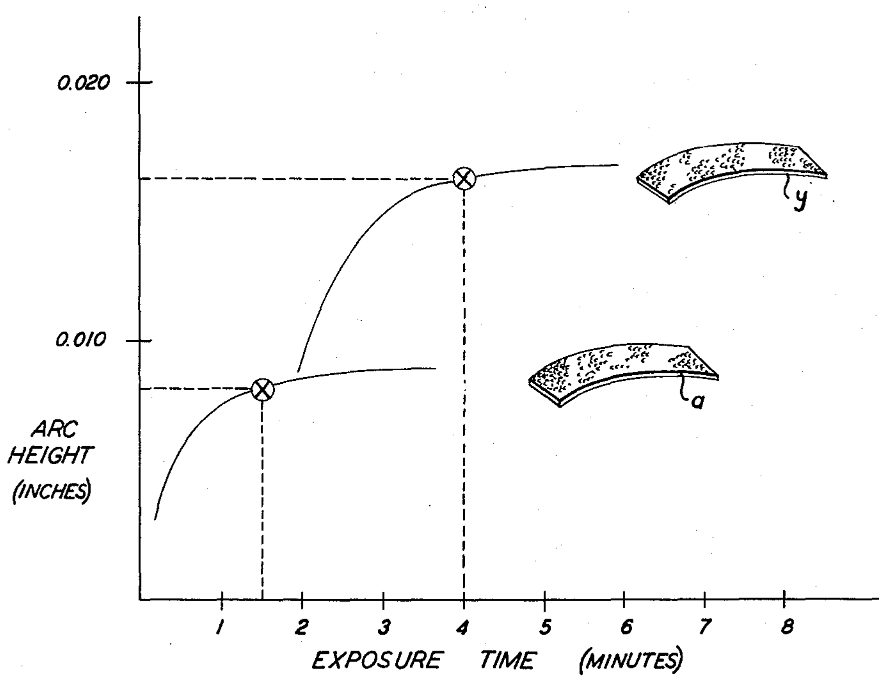

FIG. 3.

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SHOT PEEN INSPECTION TECHNIQUE

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This invention relates generally to shot peening of metal parts, and more particularly to the method of determining when a part has received full coverage or has been fully treated by the peening process.

Cold working of the outer skin of metal parts by peening has been known for several centuries. Peening with the use of high velocity shot, however, is the result of the mass production techniques of the recent era. In this process round smooth cast iron or steel shot is hurled against a metal surface to supply to the surface a series of small adjacent indentations having a curved shape. This treatment imparts a series of compressive forces in the skin of the metal which is peened. If the indentations are uniformly dispersed and the skin has had full coverage, the fatigue life of the article is greatly increased as to twisting and bending resistance. If the article is "over" peened, however, minute cracks occur in the surface due to the fact that the surface is stretched so greatly that the ductility is exhausted. These cracks are very likely to start a spreading fatigue fracture under even very low stresses.

As explained in chapter 2 of the publication entitled "Shot Peening" by the American Wheelabrator and Equipment Corporation, Second edition, 1946, the relationship between the fatigue life of an article and the stress applied is a geometrical one and when the stress reaches a certain critical value for the material concerned, a small increase in stress results in a very large decrease in fatigue life. Shot peening raises the amount of initial stress required to reach this critical value. Full coverage of the article by shot peening is very much desired since the final degrees of the process leading to full coverage may increase the fatigue life as much as several hundred percent.

Since full coverage is highly desired but "over" peening is very undesirable, the problem of determining this point of full coverage is very crucial. This problem has caused considerable difficulty when dealing with high hardness materials.

Accurate determination of this point of full coverage not only helps prevent over peening, but also aids research workers who have had difficulty in the study of high hardness items such as bearings. This is true since one variable property may not be studied exclusively when the properties are spuriously altered depending on the degree of full coverage obtained in the peening process.

Furthermore, it has been noted that there is a time interval between the moment at which full coverage is first reached and that moment when over peening begins. It is therefore desirable, for low cost production economy, to be able to determine the minimum time at which full coverage is reached when using high hardness materials.

It is therefore an object of this invention to provide a method to enable one to determine when full coverage of a metal article by shot peening has been reached. A further object is to provide a method to enable one to readily determine this time on metals having surfaces of a hardness above Rockwell "C"(RC)55. More specifically, it is an object of this invention to set forth a

procedure to determine when full coverage by shot peening has been obtained for high hardness steels. These and further objects will become more apparent from a reading of the descriptive matter to follow when read in connection with the accompanying drawings wherein:

Figure 1 is a plan view of a metal test strip shot peened in accordance with the present invention;

Figure 2 is an elevational view of Figure 1 illustrating the arc height of the test strip; and

Figure 3 is a graphical representation of the relationship between strip arc height and exposure time to shot peening of two strips in accordance with the present invention.

Broadly, the method in accordance with the present invention involves the determination of full shot peening coverage of a high hardness article by the use of test strips which are dimensionally equivalent. For convenience, standard Almen test strips may be used along with a relationship which has been discovered as existing between the peening characteristics of soft and hard-surface metals.

The time required for full shot peening coverage of a production item having a hardness of RC55 or greater is found by utilizing two dimensionally equivalent test strips: one of the material and having a hardness equivalent to that of the production item above, and the other having a specific hardness in the range of RC44–50. The full coverage times are obtained for these strips in the manner well known in the art and explained more fully hereinafter, and from these two times a ratio having a value greater than 1 is set-up. This ratio is then multiplied by the full coverage time required for shot peening a production item equivalent to the one above, but having a specific hardness equal to that of the test strip in the range of RC44–50. This latter time may be conveniently found by visual determination or by calculations based on the data which have been collected in the past on materials of this hardness and which are well known to those having ordinary skill in the art. The numerical product obtained from these factors is equal to the time required for shot peening the high hardness production items to full coverage.

The process involved may be understood more readily in the light of the following background information.

The method of treating metals by shot peening has been studied as a science and one result of this study has been the development of Almen test strips to be used for shot peening experimentation. The industry has adopted these test strips as standards. The two strips developed by Almen are labeled "A" and "C" and the specifications of these strips are given in the chart below. It is seen that the only difference between the two is thickness, thus providing a test strip for both high intensity and low intensity peening. For convenience, the Almen test strips were utilized in the conductance of experiments associated with the present invention, but it is obvious that test strips having dimensions differing from those of the Almen strips will work very well in the proposed method as long as the dimensional characteristics are alike, i.e., that the strips are dimensionally equivalent for shot peening purposes.

Characteristics and Specifications	Almen Test Strip	
	"A"	"C"
Length	3"±0.015"	(Same).
Width	0.745" to 0.750"	(Same).
Thickness	0.0510"±0.001"	0.0938"±0.001".
Hardness	Rockwell C 44–50	(Same).
Flatness	0.0015" on Almen gage No. 2.	(Same).

When these test strips such as strip **10** in Fig. 1 are shot peened, the compressive forces set up on the peened surface **12** cause the strip to bend in an opposite direction creating an "arc height" as shown by the arrow **14** in Figure 2. This bending continues until a crucial point is reached at which time the arc of the strip no longer changes. This complete cessation in change holds true if the shot is uniform in size and other conditions, such as velocity, are ideal. Under conditions as normally encountered, however, the cessation in bending is not quite so clearly pronounced, but the full coverage point may still be readily determined as the point of drastic decrease in rate of arc height change. This point in the peening process at which the arc height increases negligibly with further peening is known as the "full coverage" point, and the arc height is substantially at its maximum value at this time. This point may be determined as shown by the "*x*" marks on the respective curves in Figure 3. The corresponding test strips, *a* and *y*, for each curve as shown in Figure 3 are the relatively soft (RC44–50) and the hard (RC>55) strips, respectively.

In production operations, the only condition which is allowed to be a variable is time, since velocity of shot is easily controlled using the air-pressure or centrifugal-wheel-thrower methods of propulsion; and the same shot is recirculated continuously through the short throwing machine thus involving no variable in overall shot size. The time of peening is related to arc height of the test strips to determine at what time full coverage is accomplished.

This point of full coverage may be readily determined for metal articles other than test strips, if the articles have a hardness between about Rockwell C44 and Rockwell C50. The time may be determined by either visual means or by estimation calculations based on the data which have been collected in the past on materials of this specific hardness. The present invention utilizes this factor in the peening determination of hard surfaces as described hereinafter.

Many production items today possess hard surfaces, such as are encountered with high hardness steels, of Rockwell C55 and above. Although it is equally desirable to shot peen surfaces of this type, until now there has been no easy, inexpensive, reliable method of determinging the time of exposure corresponding to full coverage of the article. Visual means are not really adequate to determine the stopping point for surfaces having a hardness of about Rockwell C55 or harder. Even under moderate magnification (20*x*), visual observations are inadequate and unreliable to determine if the surface has been completely covered by peening or if the surface has been over-peened. Furthermore, even if it were possible using high power magnification apparatus, this type of apparatus, if used in production, would be cumbersome, time consuming, and costly.

The method which has been invented to overcome this difficulty utilizes related properties found existing between the high hardness materials and the materials for which the time of peening may readily be determined. Two physically equivalent Almen test strips, both of either the "A" or "C" type, are first heat treated. One strip is hardened to a hardness within the range of Rockwell C44–50 and the other strip is brought to the hardness of the production item which may be Rockwell C55 or above. These two strips are shot peened under like conditions and the separate times necessary to bring about full coverage are related to obtain a ratio. Full coverage is obtained when the arc height of the almen strips, as measured by a standard No. 2 Almen specimen gauge, ceases to change with further peening. The time required for full coverage of the hard metal surface such as a high hardness steel is considerably longer than that required for the softer material of RC44–50. The ratio of the high hardness time to the RC44–50 time

$$\frac{\text{(high hardness time)}}{\text{(RC44–50 time)}}$$

may be called the Almen strip factor (ASF).

$$\text{ASF}=\frac{(Ttsy)}{(Ttsa)} \tag{1}$$

where T*tsy* is the time required to shot peen to full coverage the test strip having a high hardness (RC55 or above), and T*tsa* is the time required to shot peen to full coverage the test strip having a hardness in the range of RC44–50.

The next step is to determine the time required for full coverage of the production item if it had a hardness in the range of RC44–50 and equal to that of the test strip *a*. (For convenience, call the peening time required for the production item of this hardness T*a*.)

This can be done by estimation on the basis of existing data which has been collected due to much past experimentation with metals of this hardness, or by actually imparting a hardness of RC44–50 to the standard item or an item having an equivalent peening area, and then visually determining the time necessary for full coverage when shot peening the item under equivalent production peening conditions.

It has been found that the time required for obtaining full coverage of the high hardness production item (Ty) is a multiple of the time required for the physically identical Rockwell C44–50 article (T*a*) and may be accurately found by multiplying the following factors:

$$Ty=(Ta)(\text{ASF})=(Ta)\frac{(Ttsy)}{(Ttsa)} \tag{2}$$

Obviously this mathematical set-up of the factors is arbitrary and may be altered without departing from the scope of the invention as long as the true relationship is retained. A sample determination as actually found by this method is given below.

Example

Two "C" Almen test strips were hardened to Rockwell C62 and Rockwell C50, respectively, and were given a shot peening treatment with SAE 230 chilled iron shot at 26 p.s.i. air pressure, i.e., corresponding to the nominal Almen intensity of 0.010A. The ratio of the time required for full coverage as determined by means of Equation 1 and depicted by the graph in Fig. 3 was:

$$\text{ASF}=\frac{4\text{ minutes}}{1.5\text{ minutes}}=2.7$$

It was then desired to know the time required for full coverage when shot peening a high hardness steel transmission gear with a hardness of RC62. Since the time required for this same gear having a hardness of RC50 (T*a*) can be readily found by calculations or by peening and visual determination, this time (T*a*) is now simply multiplied by the ASF previously determined. The time of 16 minutes is used for (T*a*).

Therefore:

Ty=TGEAR=(ASF)(Ta)=(2.7)(16)=43.2 minutes= time required for shot peening to full coverage a steel gear with a hardness of RC62.

This is just one example of how this new and useful method may be quickly and easily used to obtain a reliable and economical determination of the time required for full shot peening coverage of a hard-surfaced article.

Various changes and modifications of the embodiments of my invention as disclosed above may be made by those skilled in the art without departing from the principles and spirit of my invention as set forth in the appended claims.

I claim:

1. A method for determining full shot peening coverage

for a high hardness steel article comprising the steps of shot peening test strips to experimentally determine the ratio of the shot peening time required for a test strip having a hardness of Rockwell C44–50 and the time required for a test strip having a hardness equal to that of said high hardness steel article, and shot peening the high hardness steel article for a time proportional to said ratio.

2. A method for shot peening a high hardness article with a hardness of RC55 or above to full coverage comprising the steps of peening a test strip having a hardness equal to that of said high hardness article to full coverage, peening a physically similar test strip having a hardness of Rockwell C44–50 to full coverage, and finally peening the high hardness article for a time calculated from the ratio of the test strip times and the time normally required to peen under equivalent conditions a similar article having a hardness of Rockwell C44–50.

3. A method for determining the minimum full coverage time for shot peening a high hardness steel article comprising the steps of shot peening to full coverage a test strip of the same high hardness steel and a test strip having a hardness of Rockwell C44–50, and then shot peening said high hardness steel article for a time equal to the product of the time required for fully shot peening under equivalent conditions a steel article with a hardness of Rockwell C44–50 and a multiple determined from the ratio of the times required to shot peen said test strips.

4. A method for obtaining full shot peening coverage of a high hardness steel item in a minimum amount of time comprising the steps of shot peening a test strip having a hardness equal to that of said high hardness steel item to full coverage and then shot peening said high hardness steel item for a time equal to a predetermined multiple of that time required for full coverage of the test strip.

5. A method for shot peening to full coverage in the optimum time a steel with a hardness of about RC55 or above by subjecting said steel to the driven shot for a time expressed by the equation:

$$Ty=(Ta)\frac{(Ttsy)}{(Ttsa)}=(Ta)(\mathrm{ASF})$$

where

Ty is the shot peening time sought for the high hardness steel,

$Ttsy$ is the shortest time at which further shot peening of a test strip of the high hardness steel results in negligible increase in arc height,

$Ttsa$ is the shortest time at which further shot peening of a test strip under equivalent peening conditions to those of said high hardness steel test strip, which is dimensionally equivalent to the high hardness test strip but which has a hardness of Rockwell C44–50, results in negligible increase in arc height,

Ta is the minimum shot peening full coverage time under equivalent peening conditions to those associated with time Ty, for a steel having a hardness of Rockwell C44–50 and having an area equivalent to that of the high hardness steel to be shot peened, and

$$\mathrm{ASF}=\text{the ratio of }\frac{(Ttsy)}{(Ttsa)}$$

6. A method for determining full shot peening coverage on a high hardness steel article comprising the steps of shot peening a test strip of the high hardness steel for the shortest time required to produce substantially the maximum arc height of said strip ($Ttsy$), shot peening under equivalent conditions a dimensionally equivalent test strip having a hardness of Rockwell C44–50 for the shortest time required to produce the maximum arc height of said equivalent test strip ($Ttsa$), shot peening to full coverage to obtain a determinable time a first article physically equivalent to the high hardness steel article and having a hardness of Rockwell C44–50 (Ta), and shot peening under conditions equivalent to those of said first article the high hardness steel article for a time (Ty) expressed by the equation:

$$Ty=(Ta)\frac{(Ttsy)}{(Ttsa)}$$

7. A method for shot peening a high hardness metal to full coverage in a minimum time comprising the steps of shot peening to full coverage a metal having a specified area and a hardness of Rockwell C44–50 in the minimum time and recording the time required, shot peening two dimensionally equivalent test strips having a hardness of Rockwell C44–50 and a hardness equal to that of the high hardness metal to be shot peened, respectively, to determine a greater-than-one ratio from the time required for the two strips, and shot peening the high hardness metal having an area equivalent to that of said specified area, and under equivalent peening conditions, for a time which is equal to the product of the time required for shot peening said metal and the ratio determined from the test strips.

8. A method for preventing "over" peening when shot peening a high hardness steel comprising the steps of shot peening the high hardness steel for a time expressed by the following equation:

$$Ty=(Ta)\frac{(Ttsy)}{(Ttsa)}=(Ta)(\mathrm{ASF})$$

where

Ty is the shot peening time sought for the high hardness steel,

$Ttsy$ is the time at which further shot peening of a test strip of the high hardness steel results in negligible increase in arc height,

$Ttsa$ is the time at which further shot peening of a test strip, under equivalent conditions to those of said high hardness steel test strip which is dimensionally equivalent to the high hardness test strip but which has a hardness of Rockwell C44–50, results in negligible increase in arc height,

Ta is the shot peening full coverage time under equivalent peening conditions as those associated with time Ty, for a steel having a hardness of Rockwell C44–50 and having an area equivalent to that of the high hardness steel to be shot peened, and

$$\mathrm{ASF}=\text{the ratio of }\frac{(Ttsy)}{(Ttsa)}$$

9. A method of shot peening a high hardness steel to full coverage in the minimum time comprising the steps of determining the respective minimum times required to shot peen test strips of a specific high hardness steel and of a steel having a specific hardness between Rockwell C44–50 to substantially the maximum arc height of each, and then shot peening the high hardness steel for a time which is mathematically derived from the minimum times required for the test strips.

10. A method for determining the optimum shot peening time required to obtain maximum fatigue life for a high hardness steel, comprising the steps of experimentally determining the peening time (Ta) necessary for full coverage of steel (Sa) having a hardness in the range of Rockwell C44–50, and then shot peening under equivalent conditions a high hardness steel dimensionally equivalent to Sa for a time which is a multiple of the full coverage time for Sa and is equal to:

$$Ta\frac{(Ttsy)}{(Ttsa)}$$

where $Ttsy$=the minimum shot peening time required to obtain substantially the maximum arc height for a high hardness steel test strip, and $Ttsa$=the minimum shot peening time required to obtain substantially the maximum arc height for a test strip having a hardness equivalent to Sa when $Ttsa$ and $Ttsy$ are shot peened under like peening conditions.

No references cited.