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Are You Peening Too Much?

INTRODUCTION

The title of this article does not refer to the amount of peening business you are doing nor does it represent inquiry into how many parts you are peening by way of manufacturing or repair. Rather, the purpose of this article is to consider the subject of peening coverage and to consider how much coverage should be employed when peening is being done for the most common legitimate purposes including fatigue life and fatigue strength enhancement, stress corrosion resistance, and weight reduction as a result of strength enhancement achieved. It is recognized that peening nearly always conveys some benefit. One should recognize, however, that the amount of the benefit may well be determined by how the peening is performed. In addition to coverage, this likely will include considerations for intensity and for media selection and maintenance. Only the matter of coverage is treated in this article, leaving plenty of room for others to investigate other factors and parameters. The author's argument for taking up the subject of coverage is the probability that this factor represents the greatest opportunity for improving the peening process.

If you decide to read on, please do so with the understanding that it will not be possible for the author to give you recipes for peening or even to state what you must do in given circumstances. The author's thesis herein is that, in terms of coverage, generally too much peening is being done with resulting detriment to cost, equipment wear and tear, cycle time and even to part quality and durability. But the arguments come later in the article. For now, suffice to say that the author intends to briefly review principles of coverage, to consider the importance of attaining correct coverage and to present arguments and data for generally reducing coverage. The author is not so naïve as to expect that the result of this article will find many individuals or organizations ready to put concepts advanced herein into practice. Indeed if you are a peening source, you must follow specifications and directives of your customers including producing required coverage values. If you are a prime or a part manufacturer, then altering coverage requirements may require part requalification and this may be a significant financial barrier. Not the least of requirements is that considerable experimentation may be required to allow changing coverage requirements. If, at least, this article causes a few of you to consider the benefits of reduction in peening coverage and perhaps even to take some action, then the author will be gratified accordingly. If some of you at least will agree that this article has validity, then the author will likewise be pleased.

COVERAGE – SOME BASIC CONCEPTS AND TERMINOLOGY

This is a digression from the main thrust of this article, but is included for two purposes:

- provide background to readers not intimately familiar with the concept of peening coverage
- attempt to get all readers "on the same page"

First and foremost, in this article the use of the term coverage always implies uniformity, meaning that the impact sites are uniformly and randomly distributed over the peened surface area. Shown in Figure 1 are two examples of peening coverage, 1 (a) partial coverage and 1(b) complete coverage.[1] Coverage up to 100% is defined as the percentage of area exhibiting impact dents as a percentage of the total area being considered. Per SAE J2277 full (also "complete") coverage is defined as 98-100% coverage. Coverage is considered as complete at 98% because of the difficulty in resolving small non-impacted areas and the subjectivity of coverage inspection by the usual method per SAE J2277 of optically aided observation at 10-30X. Partial coverage thereby is any coverage value less than 98%. Rationale for the acceptability of allowing at least some un-impacted areas will be presented later in this article. Clearly, if one is attempting to achieve full coverage, more peening exposure will be required to make the partially covered surface resemble the fully covered surface in Figure 1. It is very important to realize is that coverage is a time-dependent quantity. It increases with exposure time. Very often peening specifications or directives call for coverage at 150%, 200% or other value greater than 100%. Coverage greater than 100% is defined as that which results from peening at a multiple of the time required to achieve full coverage: 1.5x for 150%, 2.0x for 200% and so forth. One cannot visually inspect for coverage greater than 100% because the surface appearance does not detectably change at greater than 100% coverage. Thus, we cannot truly ascertain

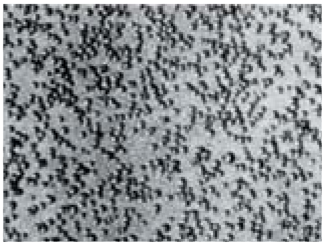

Figure 1a. Partial Coverage

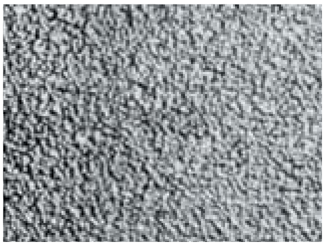

Figure 1b. Complete Coverage

the coverage associated with 1(b) unless we have determined it by observation and know that we did not exceed 100%.

Figure 2 is an exemplary graphic display, called a coverage curve, representing the progression of coverage with time of exposure in the peening process. It is determined by exposing an article or articles to peening under given parameters for various times and then determining coverage values associated with each time by observation. Let it suffice to say that no information for a coverage curve representing peening of a part or sample comes from any observations of Almen strips. Indeed, one should have no quantitative concern for Almen strip coverage except to note that it is uniform.

Referring back to Figure 2, the Y-axis is % coverage as determined by observation of the peened surface at various times and, indeed, this is the only valid means for determining coverage. Any attempt to relate coverage to exposure times or saturation time is invalid unless, perhaps, the part material is the same at the same hardness as the Almen strip which is cold-rolled SAE 1070 steel heat treated to 44-50 HRC hardness (45-48 HRC for premium strips, all the better). Again referring to Figure 2, note that the coverage initially increases relatively rapidly with exposure time and then more slowly as time progresses. In this example, it took two minutes to achieve 86% coverage and then another two minutes to achieve the additional 12% to attain full (98%) coverage.

In other words, the rate of coverage slowed as time of exposure increased though the amount of coverage continued to increase albeit quite slowly as 98% was approached. The basic reason for this is that the peening impacts occur uniformly with time (assuming constant media flow rate); however, they occur randomly over the peened surface such that some impact sites are repeatedly struck until at least 98% have been struck once.

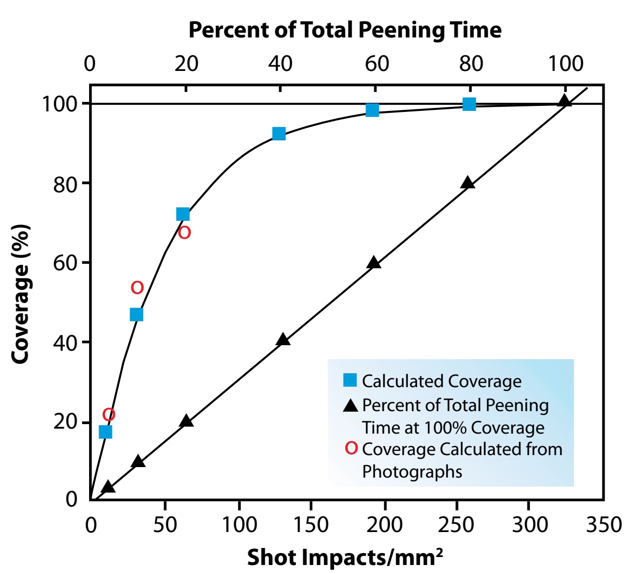

Figure 2. Exemplary Coverage Curve

AMOUNT OF COVERAGE MATTERS

The author has heard verbal expressions to the effect that coverage does not really matter so long as there is enough. It is doubtful that any of the individuals expressing such a view have a real basis for it or have ever tested it. Certainly, not much on the subject appears in the literature. Exceptions are offered here by way of Figures 3, 4 and 5. Figure 3 is a series of crack growth curves obtained after peening to different amounts of coverage. As can be seen, specimen life increased with increasing coverage from 0%, to full coverage. Unfortunately, data for peening to greater than 100% coverage were not developed or presented. Figure 4 from a 1981 paper by Horwath shows fatigue strength in 1070 steel at 45-48 HRC as a function of a parameter that includes peening time and number of impacts[1]. Though not directly in terms of coverage, this parameter implies it. Note that fatigue strength first increases with coverage, reaches a peak and then falls off

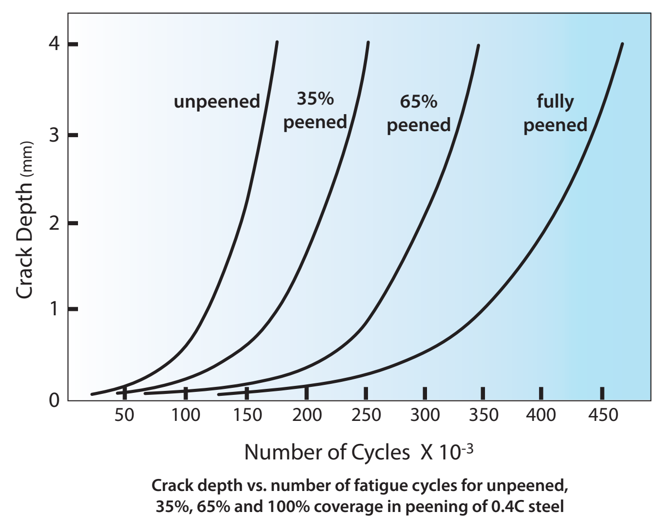

Figure 3. Crack Growth Curves Related to Coverage

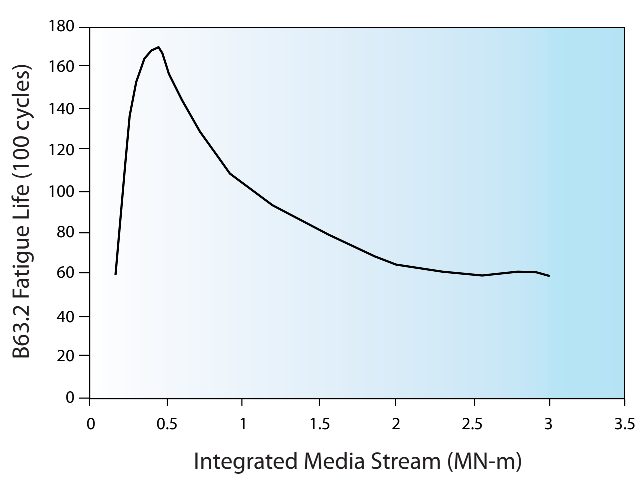

Figure 4. Fatigue Strength Related to Integrated Media Stream Energy Parameter that Relates to Coverage

as peening coverage increases further. Consideration of these data overall strongly supports a thesis that coverage matters. Unfortunately it does not directly indicate what is an optimum coverage level. Having considered such information, in 2002 the author and Prevey performed a coverage study on AISI 4340 steel, 49 HRC and published results in the ICSP 8.[2] This study revealed that the optimum coverage level for peening at 9A intensity was about 80%. Indeed fatigue results presented in Figure 5 revealed that the full benefit of peening was realized at 80% coverage and that coverage at greater than 100% resulted in decreased fatigue strength.

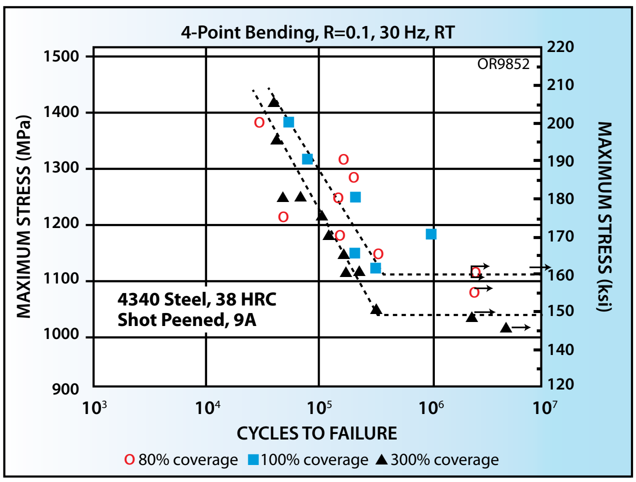

Figure 5. Fatigue Strength as Related to Coverage (80% and 100% upper curve, 300% lower curve)

The author is not advocating performing peening to less than full coverage because of issues regarding subjectivity of peening coverage determination as well as possible peening control. Similar results in later work on Inconel alloy 718 were much the same. The results of these studies, however, do present a compelling case that peening coverage does matter and that peening coverage should not exceed full coverage. Coverage by a few percent less than 98% probably would not present a problem.

So what is it about coverage in excess of full coverage that results in reduction of fatigue strength? The logical and experimental evidence point to the fact that peening creates surface defects such as folds and laps caused by overlapping of peening dents, as well as micro-cracks in some instances. The population of such defects increases as coverage increases and the defects produced are the initiation sites for fatigue cracks. Fatigue cracks emanating from such defects in overpeened (>200%) AISI 5160 spring steel are shown in Figure 6.

REDUCE PEENING COVERAGE

All things considered, there is opportunity to reduce peening coverage, hence time. Results from the Cammett–Prevey 2002 study can be displayed on a timeline as in Figure 7. The lesser time to achieve 80% and 100% coverage as compared to peening to multiples of 100% coverage should be obvious even to a casual observer. Logically limiting peening coverage has potential for economic benefits that may accrue…reduced process cycle time, less wear and tear on equipment, increase in part quality and durability. Peen lean!

SUMMARY

Returning to the subject of this article, are you peening too much? In terms of coverage, the answer is most probably yes. Is this a good thing? Most probably no. The author has presented a case for reducing coverage in peening. This can save time, reduce wear and tear on equipment and media, also reduce cost and improve part quality—all at the same time. Why would you not want to have all these benefits? If you are a part owner or design authority, the ball is in your court whereby you can succeed at this if you invest in an effort to make it happen.

Figure 6. Fatigue Crack Emanating from Micro-Lap Surface Defect in AISI 5160 Spring Steel

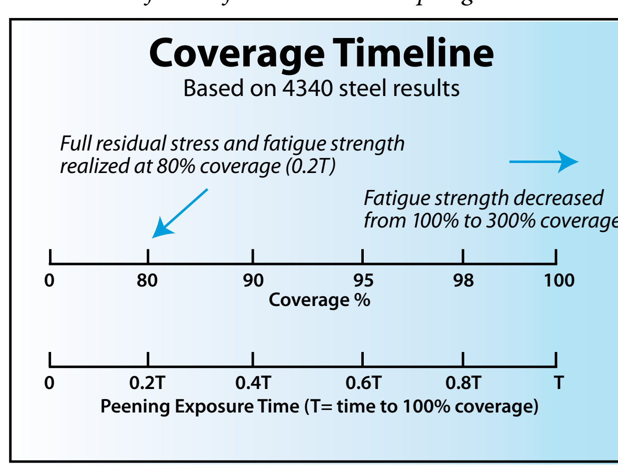

Figure 7. Timeline Illustrations of Coverage Development in an Alloy Steel

REFERENCE

1. Horwath, *Effect of Shot Peening Variables on Bending Fatigue*, Proc. ICSP1, 1981
2. Prevey & Cammett, *Effect of Shot Peening Coverage on Residual Stress, Cold Work and Fatigue in a Ni-Cr-Mo Low Alloy Steel*, Proc. ICSP8, 2002