On the Relationship of Surface Cold Work to Coverage in Shot Peening

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INTRODUCTION

Certainly, a desirable result of shot peening is creation of compressive residual stresses at the surface of a part and in near surface layers. Though often not known or seldom considered, cold work (CW) is also an inherent result of peening, and is fundamentally responsible for the creation of compressive residual stresses. Bombardment of the surface of a part by small spherical media creates plastic deformation, i.e., stretching of surface layers. Elastic resistance of underlying material, which is not plastically stretched by peening, results in compression in surface and near-surface layers. Also, not commonly known or considered is that CW can influence the stability of residual stresses from thermal exposure and mechanical applied stresses in service (Ref. 1). Discussion of this matter of residual stress stability is beyond the scope of this brief article. Readers, however, are encouraged to consult the reference supplied to determine significance to their parts and service life.

Considerable work at Lambda Technologies has been done on the subject of optimization of shot peening. Published in various places (Ref. 2 &3) and patented (Ref. 4) the work has been synopsized in a brochure available from Lambda (Ref. 5). See contact information for authors at the beginning of this article to obtain a copy of this brochure. The principal finding from peening optimization work by Lambda has been that optimum peening benefits in terms of residual stresses and fatigue strength result from peening to coverage levels less than 100%. Because CW is fundamental to residual stress creation in peening, the authors have chosen to study the relationship between CW and coverage. Incidentally, the possibility of a relationship between surface residual stress and coverage was also examined. Results are presented herein.

Specifically in this article, the authors will outline a method for cold work determination using x-ray diffraction (XRD) peak breadth and examine the relationship of CW to coverage in four diverse materials.

%CW XRD MEASUREMENT TECHNIQUE

Cold work is often expressed as a percentage (%CW) as related to the plastic strain involved. For example, 50% cold work is equivalent to a plastic strain of 0.50, 10% CW is 0.10 plastic strain, etc. Increase in %CW is manifested in XRD as an increase in diffraction peak breadth. An example of a diffraction peak profile and peak width is illustrated in Figure 1. Further discussion of measuring the %CW through the use of XRD is beyond the scope of this article, but is described in detail elsewhere (Ref. 6).

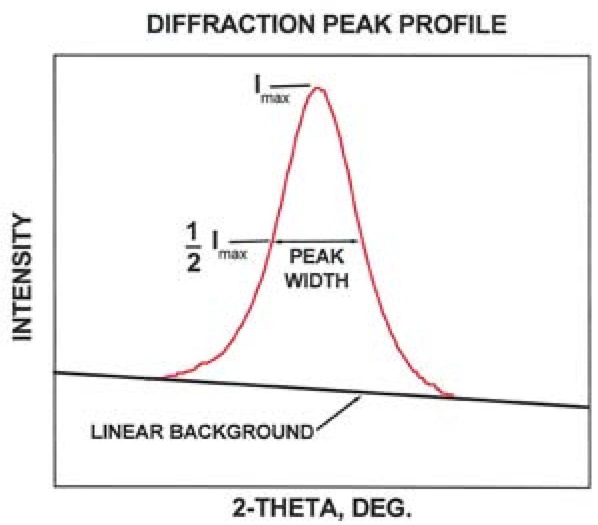

Figure 1. Graphic Illustration of FWHM Diffraction Peak Breadth Parameter

Surface values of %CW (and residual stress) can be determined non-destructively whereas determination of subsurface values require progressive layer removal to expose subsurface material for XRD measurements. Although subsurface data have been produced, the authors have confined this article to surface measurements to determine whether or not such information could be exploited as a nondestructive technique to determine optimum coverage.

RESULTS AND DISCUSSION

New information provided in this article (Figure 2) shows the relationship of surface %CW (from XRD peak breadth) to peening coverage in 4340 steel (39 HRC), Inconel 718 (STA), Ti-6Al-4V, and 7075-T6 Al respectively. Interestingly, for each of the four materials, surface %CW increases rapidly with

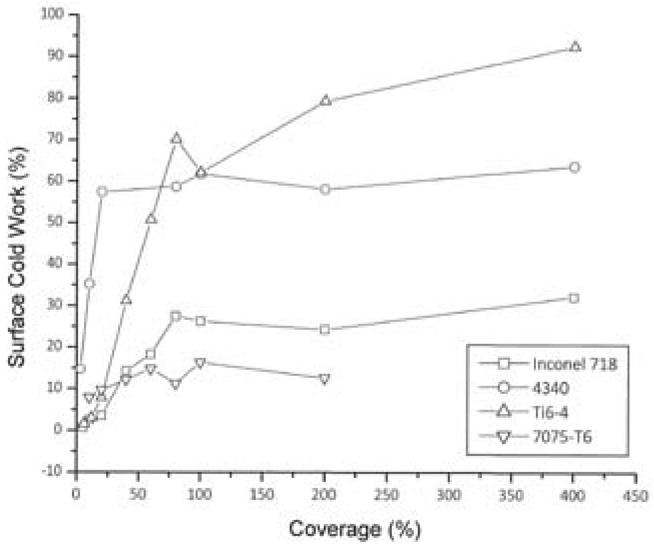

Figure 2. Relationship between Surface %CW from FWHM and Coverage for four materials

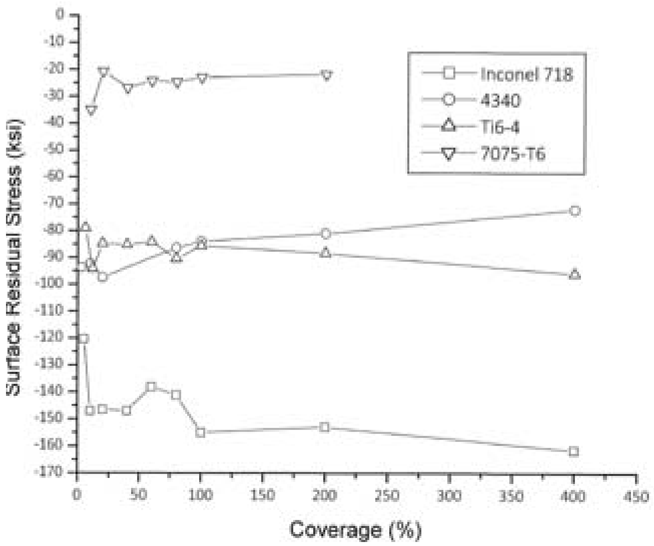

Figure 3. Relationship between Surface Residual Stress and Coverage for four materials

coverage and saturates at coverage values less than 100%. This is consistent with a previous finding that optimum peening coverage is also less than 100%. Interestingly, the saturation points for %CW for three of the four materials was very close to the 80% coverage level found as the optimum coverage level in previous studies. Potentially, therefore, monitoring of %CW at the surface may be useful as a technique for assessing peening quality. For the fourth material (4340 steel), the saturation point for surface %CW occurred at a coverage level considerably below the previously determined optimum.

The authors also examined the relationship of surface residual stress levels to coverage in the same four materials. Results are shown in Figure 3. This was done because surface residual stress levels are believed by other investigators to be useful as a nondestructive technique for determining peening quality. The trend in surface residual stress with coverage for each material appears to be unlike the trend in %CW with coverage. Except for very low coverage values, surface residual stresses for all four materials appear to be generally insensitive to coverage. There is no correlation of surface residual stresses with optimum coverage levels determined in previous work. Thus, it appears that nondestructive surface residual stress measurements will not be generally useful either to detect optimum peening coverage or as an index of peening quality.

SUMMARY

The relationship of surface %CW to coverage was explored for four diverse materials. In representative aluminum, nickel and titanium alloys, the saturation value of %CW appeared to coincide with an optimum coverage level of 80% as found in earlier investigations. For 4340 steel (39 HRC), there was no such coincidence, with the saturation %CW occurring at a coverage level significantly less than the 80% optimum level of coverage revealed in previous work. The relation of surface residual stress to coverage was also examined. No consistent correlation was found between surface residual stress and coverage in any of the four materials.

The practical benefits of optimized shot peening include up to a four-fold production rate improvement, reduced cost and media consumption (Ref. 2,3,4). The associated reduction in cold work minimizes surface damage and increases both the thermal and mechanical stability of the beneficial compressive layer. Because cold work is cumulative, practicing optimized peening can also extend the useful life of fatigue critical parts that are repeatedly peened in overhaul by reducing the increase in cold work with each cycle.

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