DUAL SHOT PEENING TO MAXIMIZE BENEFICIAL RESIDUAL STRESSES IN CARBURIZED STEELS

Aquil Ahmad
Eaton Corporation
Southfield, Michigan, USA

E. Donald Crouch, Jr.
Metal Improvement Company, Incorporated
Belleville, Michigan 48111 USA

ABSTRACT

Recent advances in shot peening technology have resulted in the development of a two stage process to maximize the beneficial surface residual stresses induced in hardened, carburized steel, such as SAE 8620, a material commonly used for gears. Steel samples with an effective case depth of 0.72mm (0.029in) were used. Shot peening conditions investigated included: a) single shot peening with: regular hardness steel shot (HRC 45-55), hard steel shot (HRC 55-62), and b) dual peening, first with hard steel shot followed by either smaller diameter hard steel shot at a lower intensity, or smaller diameter glass beads at lower intensities. To investigate the near surface effects initially observed, two samples were dual peened after surface layer removal (0.13mm-0.29mm).

Comparing the residual stress profiles obtained, the following observations were made: use of higher hardness shot produces higher magnitude residual stresses, dual peening produces higher magnitude residual stresses; shot peening after the removal of the surface upper transformation products results in increased surface residual compressive stresses for similar shot peening parameters.

IT IS widely recognized that compressive residual stresses enhance the bending fatigue life in metal components, such as gears. This study was initiated to investigate improved shot peening parameters under various peening conditions to permit the maximization of compressive residual stresses in carburized steel. Conventionally carburized and hardened steel blocks of SAE 8620, (see Figure 1) 76mm x 51mm x 13mm (3inx2inx1/2in), having a case depth of 0.58mm-0.76mm (0.023in-0.030in), were subject to several shot peening conditions for the development of residual compressive stresses. Residual stress values were determined by x-ray diffraction techniques.

A microstructure and hardness determination was conducted on a representative specimen from the same batch of heat treated steel blocks. Figure 2 shows grain boundary oxidation extending to 0.01mm. The core and case microstructures are shown in figures 3 and 4 respectively. Figure 4 indicates the presence of upper transformation products at the surface. The case depth hardness profile is shown in figure 5. The lower hardness value of 51 HRC, near the surface, is attributed to the presence of upper transformation products. The effective case depth was measured to be 0.72mm (based upon 50 HRC criteria).

The residual stress measurements were conducted by an independent laboratory using x-ray diffraction techniques per SAE J784a. The residual stress measurements were performed in the longitudinal direction as shown in figure 1. The size of the irradiated area was 1.27mm x 5.08mm, with the short axis in the direction of measurement.

The residual stress data obtained from the samples is plotted in figures 6, 7, 8, and 9. Figure 7 shows data points in addition to those presented in figure 6 from the surface and to 0.02mm beneath the surface.

Figure 8 is a plot of the residual stress data obtained from samples shot peened after the removal of undesirable surface layers, one by electropolishing (#89), the other by grinding (#86) (see Table 2). Figure 9 is a composite plot of figures 6 and 8.

Shot peening conditions were selected to compare the effects of single and dual peening with the as-carburized condition. Two additional samples were prepared (one was ground, one was eletropolished) to remove intergranular oxidation and upper transformation products found to a depth of 0.01mm (0.0004in.). Table 1 presents the shot peening conditions that were studied.

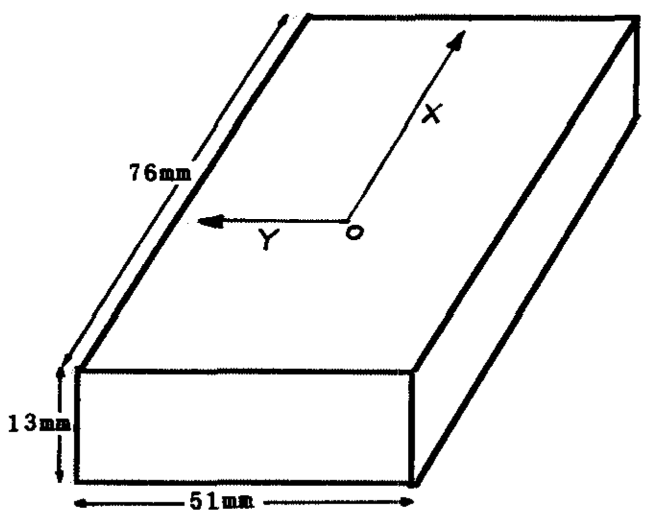

Figure 1 Sketch of steel blocks. used in this study, showing. orientation of residual stress. measurement along OX direction..

The steel shot and glass bead peening was accomplished using air-blast type equipment. The number of nozzles, distance from the workpiece, air pressure and nozzle angle were varied to obtain the peening intensities shown in Table 1. Full coverage was verified using Dyescan tracer liquid as explained in paragraph 6.10 (b) of MIL-S-13165B*. All nozzles had 6.25mm air jets and 9.53mm nozzle ends.

*Military Specification, "Shot Peening of Metal Parts", MIL-S-13165, Revision B, Amendment 2, 25 June 1979.

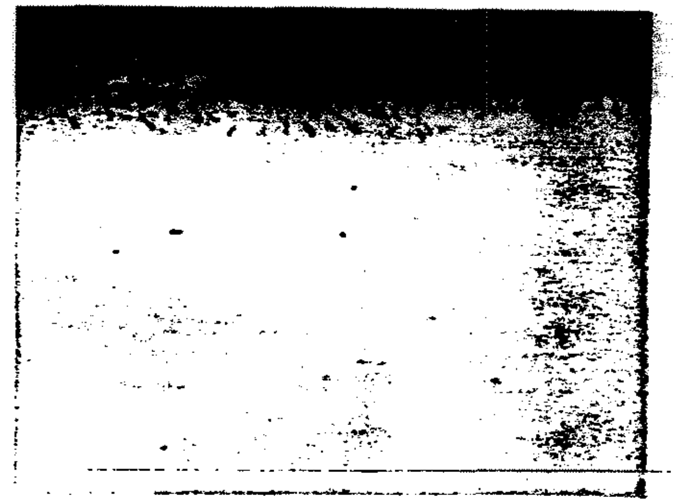

Figure 2 Cross section through sample #81, showing grain boundary oxidation (SAE 8620 carburized and hardened, 500x).

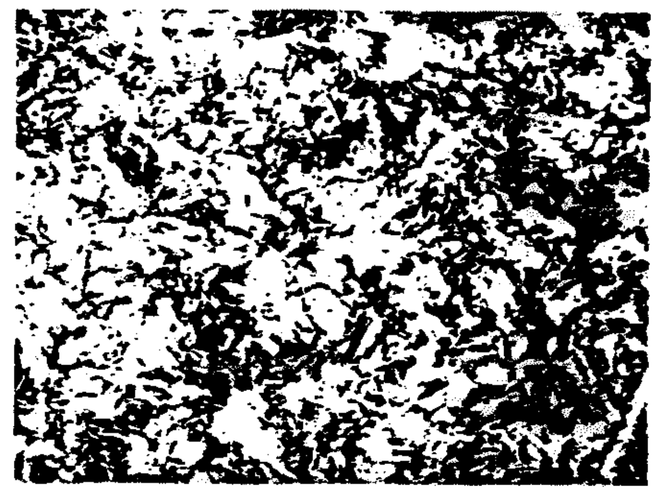

Figure 3 Core microstructure sample #81, (SAE 8620 carburized and hardened, 500x).

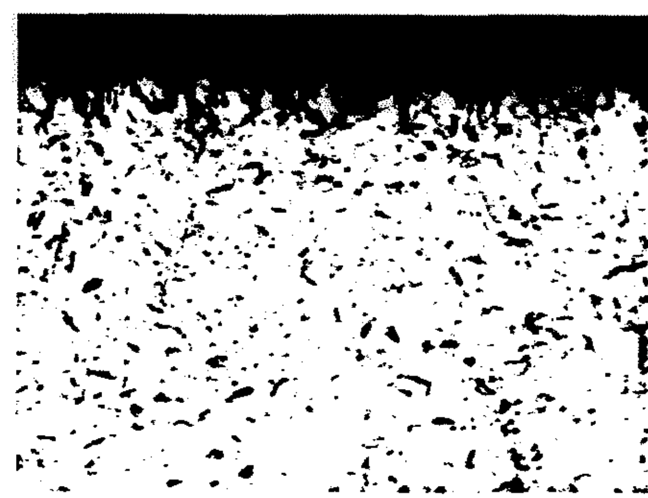

Figure 4 Cross section through sample #81, showing case microstructure (SAE 8620 carburized and hardened, 500x).

Table 1
Shot Peening Conditions Studied

Sample	Primary Treatment: Shot Size(1)	Primary Treatment: Intensity(2)	Secondary Treatment: Shot Size(1)	Secondary Treatment: Intensity(2)
83	Not Shot Peened		-	-
84	230	0.46A (18A)	-	-
85	230H	0.56A (22A)	-	-
87	230H	0.56A (22A)	110H	0.15A (6A)
88	230H	0.56A (22A)	GP100	0.13A (5A)
89	230H	0.56A (22A)	GP100	0.13A (5N)
89(3)	230H	0.46A (18A)	GP100	0.13N (5N)
86(4)	230H	0.46A (18A)	GP100	0.13N (5N)

(1)Shot sizes conform to MIL-S-13165B, regular hardness cast steel shot is HRC 45-55, H denotes harder cast steel shot (HRC 55-62), GP denotes glass beads, MOH's hardness 5.5.
(2)Almen intensity A Strip, N Strip, in mm, English units in parenthesis.
(3)0.29mm removed prior to peening by electropolishing.
(4)0.13mm removed prior to peening by grinding, with coolant.

Table 2
Shot Peening Variables

Sample		84	85	87(1)	88(1)	89(1)	89(2,11)	86(2,12)
Oscillation	(3)	127	127.	127.	0	0	0	0
Intensity	(4)	0.46A	0.56A	0.15A	0.13A	0.13A	0.13A	0.13A
No. of Nozzles	(5)	5	4	4	2	2	2	2
Nozzle Distance	(6)	102-127	102-127	102-127	102-127	152-178	152-178	152-178
Nozzle Angle	(7)	80	60	45	45	30	30	30
Air Pressure	(8)	550	550	310	550	70	70	70
Shot Velocity	(9)	32	32	23	32	9	9	9
Time	(10)	20 Min	5 Min	40 Sec	20 Sec	40 Sec	40 Sec	40 Sec.

(1) Lists secondary treatment, primary treatment same as #85.
(2) Lists secondary treatment, primary treatment 0.46A.
(3) Nozzle movement, mm.
(4) Almen Intensity, mm.
(5) All nozzles with 6.35mm air jets and 9.53mm nozzle ends.
(6) Distance from nozzle end to workpiece, mm.
(7) Degrees from horizontal rotating workpiece.
(8) Gage pressure, kPa.
(9) Estimated velocity, meters per second*.
(10)Time to achieve 200% coverage **, samples 86,87,88,89 show times for second peening, first peening same as 85.
(11)0.29mm removed prior to peening by electropolishing.
(12)0.13mm removed prior to peening by grinding, with coolant.

*J.M. Lessells, R.F. Brodrick, "A Critical Study of the Stress Distribution Produced by Shot Peening", SAE Publication.
**Military Specification, "Shot Peening of Metal Parts", MIL-S-13165, Revision B, Amendment 2, 25 June 1979.

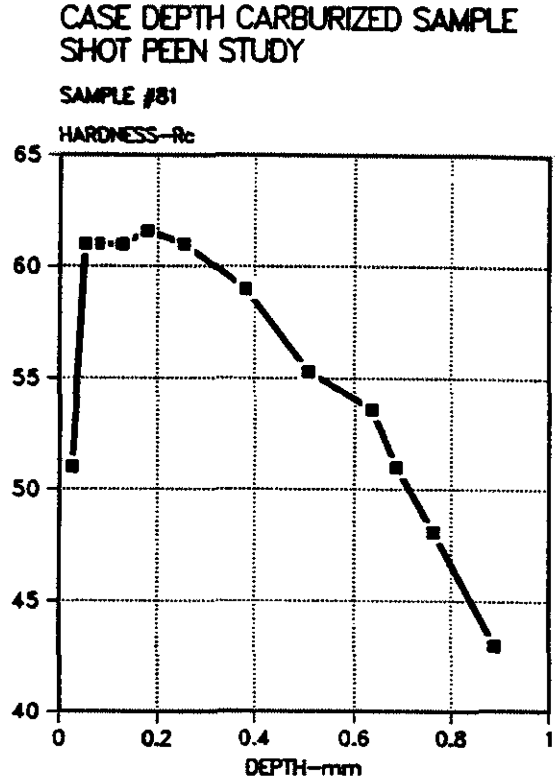

Figure 5 Hardness profile sample #81, SAE 8620 carburized and hardened.

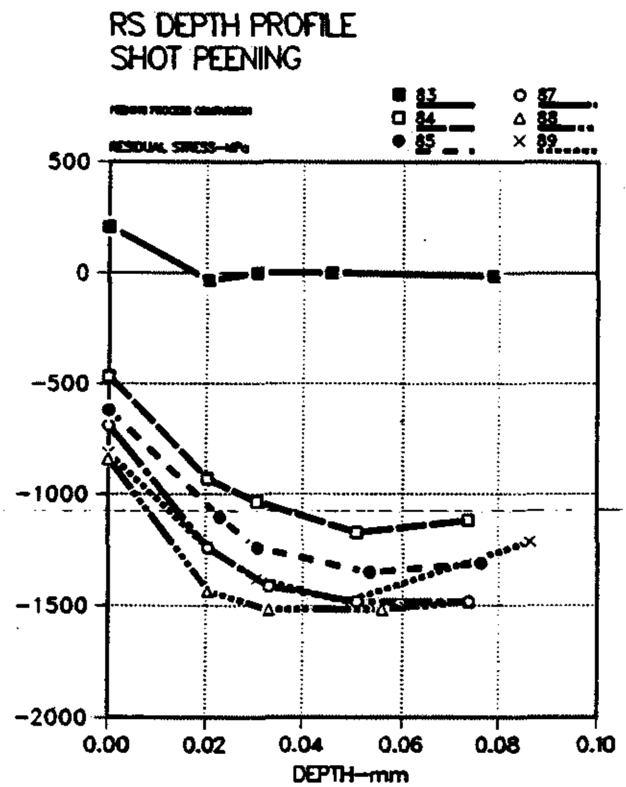

Figure 6 Comparison of x-ray diffraction residual stress profiles for as-carburized and shot peened samples.

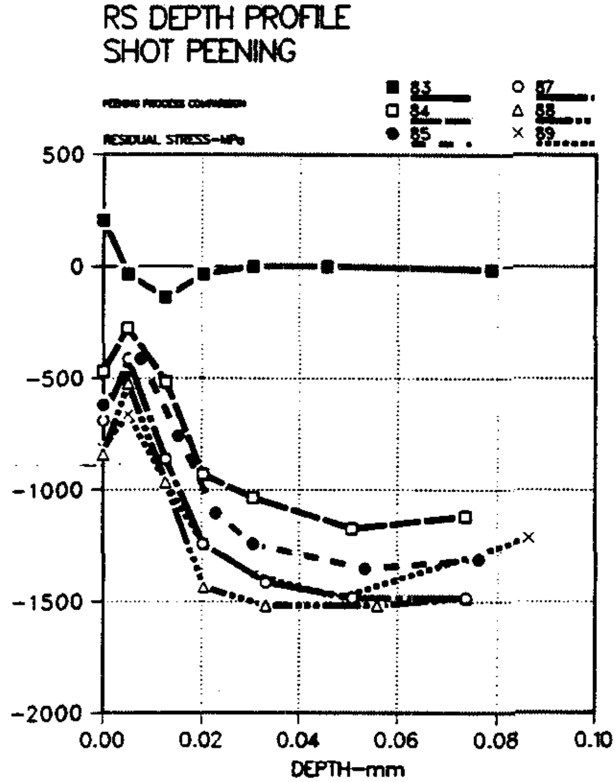

Figure 7 Comparison of x-ray diffraction residual stress profiles for as-carburized and shot peened samples including measurements between the surface and 0.02mm.

DISCUSSION OF FIGURES 6,7,8,9, TABLE 3

FIGURE 6-Comparison of residual stress profiles for as-carburized, single peened and dual peened samples is shown. The base line residual stress values were obtained from the as-carburized sample #83 shown in the figure. The tensile residual stress at the surface is attributed to the presence of upper transformation products and grain boundary oxidation.

The regular hardness (HRC 45-55) shot produced a relatively lower compressive residual stress profile in sample #84, than the comparable treatment with hard shot (HRC 55-62) seen in sample #85. Comparing samples #87, #88 and #89 to #85, improvement in compressive residual stress profiles is observed, the magnitude dependent upon the secondary peening parameter. Sample #88 provided the largest improvement in compressive residual stress at the surface. The residual stress values of samples #87 and #88 are the same at 0.074mm below the surface.

FIGURE 7-This shows additional data points between the surface and 0.02mm. A reduction in compressive residual stress value is observed at 0.005mm in all the shot peened profiles from that measured at the surface. This phenomenon is attributed to the presence of the upper transformation products near the surface as explained earlier.

Table 3
Surface Finish of Samples

Sample No.	Ra
83	75
84	40
85	55
87	55
88	50

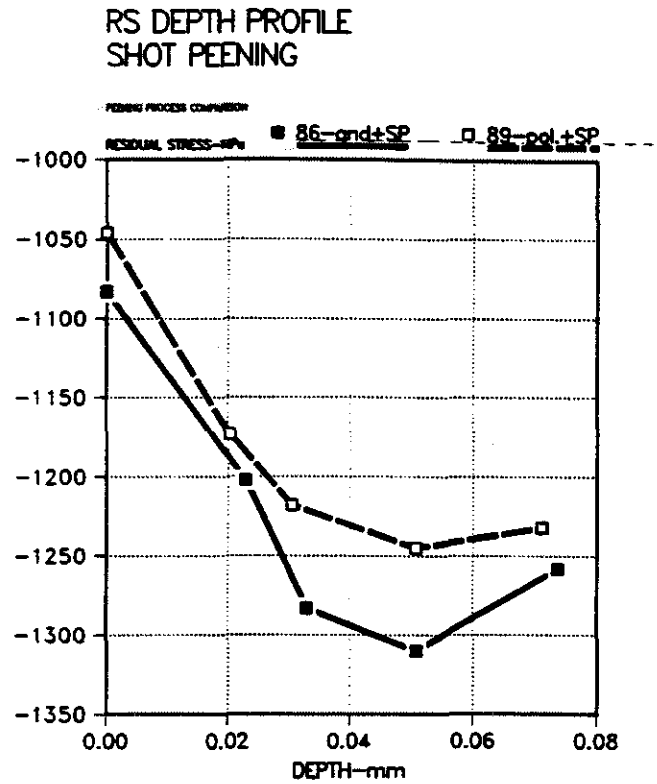

Figure 8 Comparison of x-ray. diffraction residual stress. profiles, shot peened after the. removal of surface layers. (0.13mm #86, 0.29mm #89)..

FIGURE 8-Significantly higher compressive residual stresses are observed at the surface on samples #86 and #89 (shot peened after the removal of surface layers explained in Table 2).

FIGURE 9-This effectively compares the difference in residual stress profile between shot peening as-carburized samples to that of as-carburized and surface layer removed samples when upper transformation products and grain boundry oxidation exists.

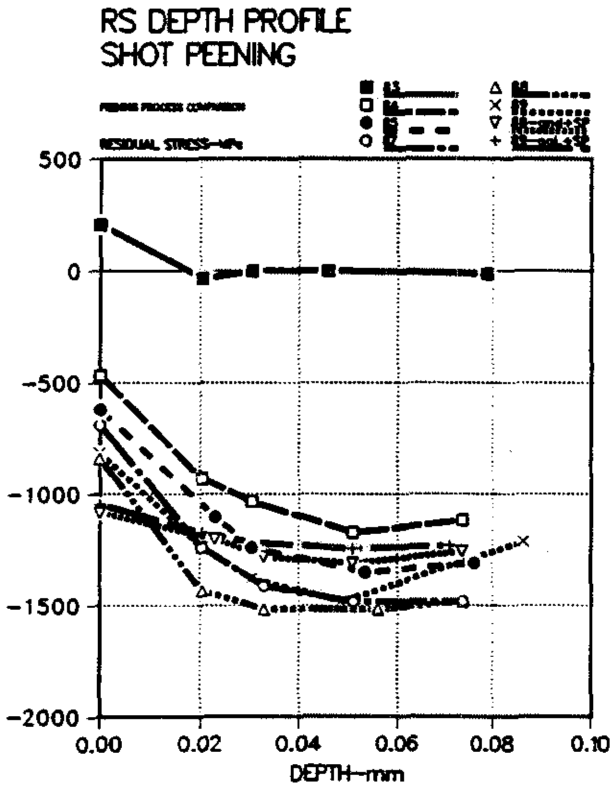

Figure 9 Comparison of x-ray. diffraction residual stress. profiles, composite of figures. 6 and 8..

TABLE 3-Shot peened samples had a different surface finish than the as-carburized sample. The shot peening parameters have a direct effect upon the surface finish.

CONCLUSIONS

Based on the data generated from this study the following conclusions are drawn:

(1) Shot peening develops surface and sub surface compressive residual stresses.

(2) Shot hardness affects the magnitude of compressive residual stresses generated. Increasing the shot hardness will typically produce higher values of compressive residual stress.

(3) Dual peening, that is, high intensity shot peening followed by a lower intensity and smaller size shot increases the magnitude of compressive residual stress.

(4) Shot peening after the removal of the upper transformation products, results in increased surface compressive residual stress for similar shot peening conditions.

ACKNOWLEDGEMENT

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