FACTORS THAT INFLUENCE ALMEN STRIP ARC HEIGHT

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ABSTRACT

Almen strips, developed in the 1940s, are standardized steel coupons whose curvature is used to determine intensity, the impact energy level of a shot stream. Proper application of this system depends on a number of factors related to the strip itself, its mounting block and its use techniques. Specifications contain Almen strip and Almen block dimensional and hardness tolerances. Tests were conducted to determine which of these tolerances significantly affect arc height measurement accuracy. Of factors related to Almen strip use, the use of prebow compensation is shown to be significant. Another factor evaluated was the area of strip coverage. Peening only a central portion of the strip to accommodate small blast pattern peening of small parts was shown in some cases to be an accurate representation of the process. Another study evaluated blocks with different hold down screw placement for potential application to processes in which interference with the screws is an issue. The area factor also relates to measuring intensity of and to applications requiring "shaded strip" determination of intensity in small holes or small slots.

KEY WORDS

Almen strips, Almen blocks, arc height accuracy, hardness, dimensions, prebow, strip coverage

ALMEN STRIP HARDNESS AND THICKNESS

Almen strip hardness as an arc height accuracy factor is shown to approximate .0001in per HRc point within the HRc 44-50 specification range as shown in the data plot of Figure 1. (1) Most Almen strips fall in the middle of the range, HRc 46-49, suggesting a small arc height variation range of only .0003in. in practice.

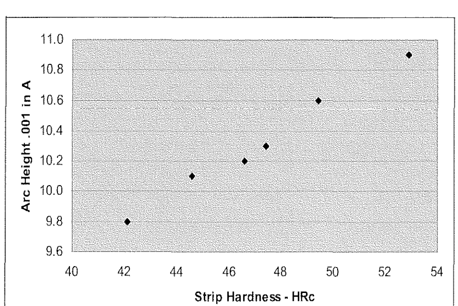

Figure 1 Arc Height vs Almen Strip Hardness

The effect of Almen strip thickness variations can be estimated by plotting arc height against strip thickness as shown in Figure 2 using the known correlation ratios for A to C strips of 3.5 and N to A strips of 3.0. Such a manipulation suggests that a .009inA arc height could vary by $\pm$.0003in within the .050-.052in A strip thickness tolerance.

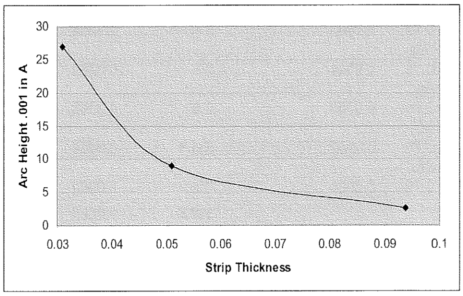

Figure 2 Arc Height vs Strip Thickness

Thickness measurements of a 48 piece set of A Almen strips showed a total range of .0510-.0516in, averaging .0513in with a standard deviation of .0018in. This thickness range is estimated to produce an arc height range of less than .0002in. Taking hardness and thickness variations together suggests that the total arc height effect should be less than .0005in. While not trivial, such variations are manageable.

ALMEN STRIP DIMENSIONS

Dimensional tolerances were shown to have no measurable effect on arc height accuracy by testing the effect of significant length and width reductions as shown in Table 1. Type C strips were used for the tests, peened with S550 shot at 70 psi. Each test arrayed two standard and two reduced dimension strips on a turntable. The narrowed strips were carefully ground to the minimum dimension (.72 in.) that could still be securely held by the holder screws. The shortened strips were cut with a thin abrasive wheel. All were prebow measured before and after cutting for distortion. None was changed by more than .0003in.

TABLE 1 ARC HEIGHT VS STRIP DIMENSIONS

Strip Width	Peened Arc height	Strip Length	Peened Arc height
0.72	0.0062	2	0.0063
0.72	0.0063	2	0.0064
0.72	0.0063	2.5	0.0065
0.72	0.0063	2.5	0.0064
Std 0.75	0.0064	2.5	0.0064
Std 0.75	0.0062	2.5	0.0065
Std 0.75	0.0062	Std 3	0.0063
Std 0.75	0.0064	Std 3	0.0062
		Std 3	0.0065
		Std 3	0.0065
		Std 3	0.0064
		Std 3	0.0064

ALMEN STRIP PREBOW COMPENSATION

The simplest and most effective improvement in arc height measurement accuracy is prebow compensation, which involves only using the increase in arc height caused by peening. In its simplest form it involves zeroing the Almen gage with the strip – only workable for single strips. For multiple Almen locations the pre-peen arc heights are measured and marked on the side of the strip to be in contact with the holder – whether the prebow is convex or concave is critical. After peening, prebows curving in the same direction as the peened curvature are subtracted. The opposite curvatures are added. The Table below shows a significant reduction by prebow compensation in data scatter expressed as "range".

TABLE 2 PREBOW COMPENSATION

A strips S110 70 psi .350 nozzle										
As Peened	0.0064	0.0060	0.0061	0.0057	0.0063	0.0064	0.0061	0.0064	Range	0.0007
Prebow Comp	0.0062	0.0062	0.0061	0.0061	0.0061	0.0061	0.0063	0.0060	Range	0.0003
A strips S110 70 psi .350 nozzle										
As Peened	0.0067	0.0064	0.0071	0.0070					Range	0.0007
Prebow Comp	0.0065	0.0064	0.0065	0.0064					Range	0.0001
A strips S110 70 psi .250 nozzle										
As Peened	0.0104	0.0102	0.0097	0.0096					Range	0.0008
Prebow Comp	0.0098	0.0100	0.0100	0.0099					Range	0.0002
A strips S110 70 psi .250 nozzle										
As Peened	0.0101	0.0103	0.0103	0.0101	0.0107	0.0104	0.0100	0.0096	Range	0.0110
Prebow Comp	0.0101	0.0101	0.0101	0.0101	0.0103	0.0101	0.0102	0.0100	Range	0.0003
A strips S550 70 psi .350 nozzle										
As Peened	0.0247	0.0246	0.0245	0.0248					Range	0.0003
Prebow Comp	0.0245	0.0244	0.0246	0.0245					Range	0.0002
Commercial 1/8 in HRc 48 strip S550 70 psi .350 nozzle										
As Peened	0.0074	0.0040							Range	0.0034
Prebow Comp	0.0040	0.0042							Range	0.0002

These tests and all others reported were carried out in a small machine equipped for direct pressure using a MagnaValve for shot flow control and a four place Almen holder turntable.

An earlier published study(1) by histograms of strip arc heights in Figure 3 showed that prebow compensation produces a normal distribution of arc heights.

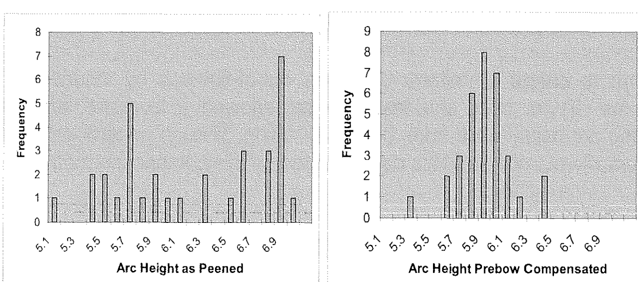

Figure 3 As Peened and Prebow Compensated Histograms

ALMEN BLOCK CHARACTERISTICS

Evaluation of Almen holder blocks concentrated on two major characteristics, hardness and flatness. An additional characteristic, the longitudinal spacing of the hold down screws, was examined because of potential use for peening processes needing more space without screw head interference. Such processes include Roller Burnishing, Laser Shock Peening, Low Plasticity Burnishing and Flapper Peening.

ALMEN BLOCK HARDNESS

Block hardness was evaluated by showing Almen arc height inaccuracies caused by blocks substantially below the 57 HRc required by SAE J442 and by extension AMS 2430, 2432 and the company specifications that reference J442. Unfortunately AMS-S-13165 by omission allows soft mild steel blocks. The problem, as personally observed by the author, is that soft blocks allow deep dimpling in the area around a peened Almen strip. Subsequently mounted strips can easily "ride up" on the dimpled area and produce erroneous arc heights.

ALMEN BLOCK FLATNESS

Almen block flatness of 0.1mm (.004in.) is required in J442. One company specification requires 0.025mm (.001in.). Since testing all possible out-of-flatness modes is impractical, it was decided to test the worst case situation of high points in the block center. Center mounted shims of .002in., .005in. and .010in. were used to measure effects on Almen arc height accuracy. The results are depicted in Figures 4 and 5.

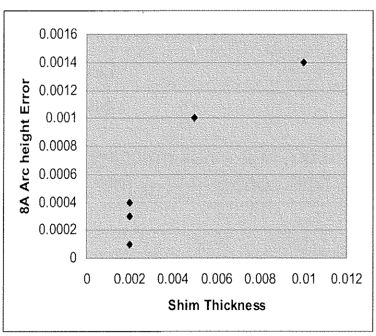

Figure 4 A Strip Shim Errors

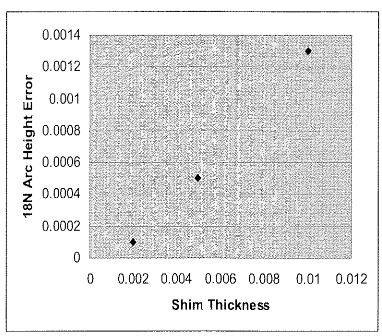

Figure 5 N Strip Shim Errors

An attempt to create a uniform curvature out-of-flatness by inserting a C strip between the .010in. shim and test strip still showed a localized strip bend and reduced the arc height error from .0014in to .001in. Though general conclusions are difficult, specific out-of-flat blocks can be tested by this comparison method.

ALMEN BLOCK SCREW PLACEMENT AND PEENED LENGTH

Longitudinal hold-down screw placement was evaluated using a special block with spacings of 1.5in, 2in and 2.5in. Spacing in J442 and AMS-S-13165 is nominally 1.57in. All are greater than the Almen gage arc measuring distance of 1.25in. Evaluation of the spacing was carried out in combination with evaluation of the necessity to peen more than the 1.25in length. One could suppose that peening more than the measured length should be unnecessary. At low arc heights with the standard block this supposition works, but at higher arc heights and with increased screw spacing the picture changes, suggesting caution for application by some of the deeper peening processes, or perhaps just the development of correlation factors. Table 3 shows negligible arc height differences between longitudinal screw spacings from the standard at 1.57 in and 1.5 in, 2 in, and 2.5 in for strips peened along their full lengths.

Table 3 Longitudinal Screw Spacing

Strip Type	Longitudinal Screw Spacing	Peened Length	Arc Height
C	Std	Full	0.0070
C	Std	Full	0.0070
C	2.5 in	Full	0.0071
C	1.5 in	Full	0.0071
A	Std	Full	0.0245
A	Std	Full	0.0244
A	2 in	Full	0.0246
A	2.5 in	Full	0.0245
N	Std	Full	0.0277
N	Std	Full	0.0274
N	2.5 in	Full	0.0266
N	2 in	Full	0.0275
N	Std	Full	0.0274
N	Std	Full	0.0267
N	2.5 in	Full	0.0269
N	2.5 in	Full	0.0273

Following the previous study of full strip peening with extended longitudinal screw spacings, experiments with shorter peened lengths were conducted to determine whether processes that might interfere with the screw heads would be allowed to peen only the strip area between the heads. The test data in Table 4 show that arc height errors decrease as the peened length approaches the longitudinal screw spacing. Figure 6 makes this easier to see for the N and A strips. The largest error conditions also showed curvature of the strip before the screws were released.

Table 4 Screw Spacing and Peened Length

Nom Arc Height	Strip Type	Longitudinal Screw Spacing	Peened Length	Arc Error	Spacing minus Peen length	Curve before Release
0.028	N	Std	1.25	0.0007	0.32	0.002
0.028	N	2.5 in	1.25	0.0037	1.25	0.022
0.028	N	Std	1.5		0.07	
0.028	N	2.5 in	1.5	0.0026	1.00	0.021
0.028	N	Std	1.75		-0.18	
0.028	N	2.5 in	1.75	0.0014	0.75	
0.028	N	Std	2		-0.43	
0.028	N	2.5 in	2	0.0006	0.50	
0.028	N	Std	1.5		0.07	
0.028	N	2 in	1.5	0.0013	0.50	
0.028	N	Std	1.75		-0.18	
0.028	N	2 in	1.75		0.25	
0.024	A	Std	1.5	0.0002	0.07	
0.024	A	Std	1.75		-0.18	
0.007	C	2 in	1.25	0.0003	0.75	

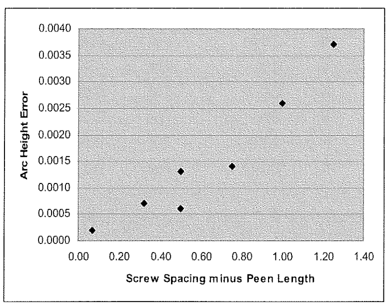

Figure 6 Arc Height Error - Screw Spacing and Peened Length

SHADED STRIPS

Correlations of arc heights from non-standard use of Almen strips to the J442 and J443 procedures are legitimate and specification controlled. The two most common are the magnetic holder used for flapper peening in MIL-R-81841 and "shaded strips" described in several company specifications. The latter utilize narrow transverse stripe peening of (usually an N strip) in a special fixture simulating a small feature – like a hole. Correlation is a simple matter of flat table peening of full A strips with N strips masked to expose the stripe – at the high and low of the A intensity range. Some specifications allow longitudinal stripe peening of A strips. Examples of correlations are shown in Figures 7 and 8. These are not to be used directly because other peening conditions will likely produce different correlations. Simple masking with a double layer of vinyl tape was found adequate. To substantiate the effectiveness of this masking, an A strip with a single layer was peened at .008in A intensity and showed no arc height.

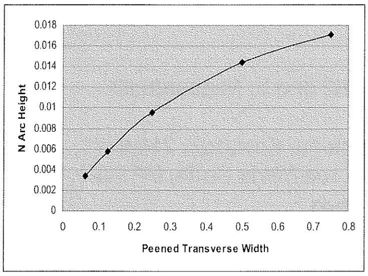

Figure 7 Transverse Shaded N Strips

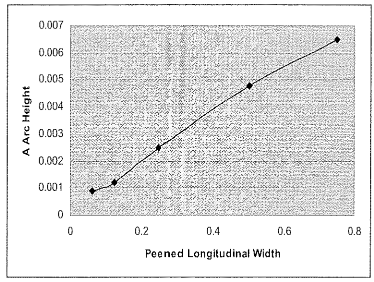

Figure 8 Longitudinal Shaded A Strips

CONCLUSIONS

- Almen strip hardness and thickness tolerances produce measurable but manageable arc height variations, while length and width tolerances appear unnecessarily tight.
- Prebow compensation is very significant for control of arc height variability.
- Peening only the Almen strip center in small blast area processes was shown without arc height error as long as the area between the screws is covered.
- Alternative Almen block screw longitudinal placement to accommodate processes that might have interference would not produce arc height error as long as the area between the screws is covered
- Shaded strip correlation was shown to be not difficult.

REFERENCES

1. Bailey, P.G., "Almen Strip Reliability"; The Shot Peener, 1991