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# Performance of Almen Strips which are Straightened after Tempering

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## 1 Introduction

Almen strips are test coupons used to determine the intensity of the shot blast stream during the shot peening process. Strips are manufactured in accordance with SAE J442 [1]. Standard manufacturing practices involves cutting strips from (soft) coil stock, heat treating and quenching to HRC 62 and then heat setting with clamping during tempering to provide strip flatness and low values of compressive stress on both sides of the strip. An alternative (hybrid) method of manufacturing was investigated. The method involved hardening and tempering (44-50 HRC) strip stock in a coil, straightening at room temperature and then cutting to length. One piece of each type of strips (standard and hybrid) was examined by X-ray diffraction to obtain residual stress distribution measurements. Readings were taken on both sides of these strips prior to peening and the results are shown in Figure 5. Differences in strip response to peening of 30 strips of each type were evaluated using two shot sizes and four Almen intensities. Tests at various peening intensities were conducted to compare the performances of standard strips and these hybrid strips.

## 2 Design of Experiment

A direct-pressure single-nozzle robotic peening machine was used to perform all of the peening. The test matrix utilized small and large size shot and low and high intensities. Standard strips were used to develop Almen saturation curves at selected machine settings. These same settings were then used for subsequent peening tests.

The peening was conducted using the matrix of parameters shown below in Table 1. Almen holders were mounted on a rotary turntable. Standard and hybrid strips were alternately placed in sequence around the table periphery.

| Trial | Media | Air Pressure PSI | Angle | Almen Intensity Lower Spec Limit LSL (inch) | Almen Intensity Target (inch) | Almen Intensity Upper Spec Limit USL (inch) |
|---|---|---|---|---|---|---|
| 1 | CW14 | 32 | 45° | .0034 | .0054 | .0074 |
| 2 | S-330 | 25 | 45° | .0052 | .0072 | .0092 |
| 3 | CW14 | 85 | 70° | .0082 | .0102 | .0122 |
| 4 | S-330 | 75 | 80° | .0179 | .0199 | .0219 |

**Table 1.** Machine parameters used for testing

## 3 Results and Discussion

Results are summarized in Table 2 and shown in Figures 1-4. There was a large variation in mean Almen intensity for Trial 1 but only a small variance at the higher intensities. One very unexpeced result emerged between the two types of strips. There was a bi-modal distribution of Intensities in the hybrid strips as shown in the histograms and values for Cp and Cpk. The bi-modal distribution of the hybrid strips may be due to the differences in compressive or tensile stresses present prior to peening. Since we did not perform X-ray diffraction to analyze all of the strips prior to peening we could not determine which side (tensile or compressive) of any given hybrid strip was peened and therefore we could not definitively assign a cause for this performance. Further investigation would be required to understand the mechanism involved.

| | Mean | | | Std Dev | | Cp | | Cpk | |
|---|---|---|---|---|---|---|---|---|---|
| | Standard | Hybrid | Variance | Standard | Hybrid | Standard | Hybrid | Standard | Hybrid |
| Trial 1 | .0054 | .0046 | .0013 | .0002 | .0008 | 3.005 | .8139 | 2.99 | .5101 |
| Trial 2 | .0072 | .0068 | .0004 | .0002 | .0007 | 3.04 | .9493 | 3.02 | .7452 |
| Trial 3 | .0102 | .0098 | .0004 | .0002 | .0008 | 3.252 | .8371 | 3.209 | .5804 |
| Trial 4 | .0199 | .0192 | .0007 | .0004 | .0007 | 1.754 | 1.009 | 1.737 | .6324 |

**Table 2.** Summary of peening tests

## 4 Summary

It appears that hybrid Almen test strips can be manufactured that meet the five attributes (length, width, thickness, hardness and flatness) cited in the SAE J442 specification for test strips but the performance, when submitted to peening, may not always be the same compared to standard strip manufacturing. Although it is surmised that tensile-compressive residual stress may be the cause of these differences more testing should be done which would include determining the influence, if any, of the roll radius prior to straightening. A tighter roll-radius might impart a higher level of tensile stress on one side of the hybrid strip as compared to a large roll-radius.

Another interesting observation was made regarding the hybrid bi-modal distributions. It appears that the higher bi-modal readings of the hybrid strips aligned generally with the standard strip performance while the balance of the bi-modal readings of the hybrid strips were significantly lower value. Reflecting upon the differences of tensile/compressive pre-peen stresses shown in Figure 5 one could speculate that the higher bi-modal readings may have resulted from peening the compressive side of the hybrid strips while the lower readings may have been the result of peening the tensile side of the hybrid strip. Estimating the variance of the average of the lower bi-modal group as compared to the standard would yield significant errors in a production situation. Comparing the standard strip mean values to the hybrid strip mean values (both bi-modal groups) will not disclose the severity of the situation. Obviously more investigation is needed to explain this performance.

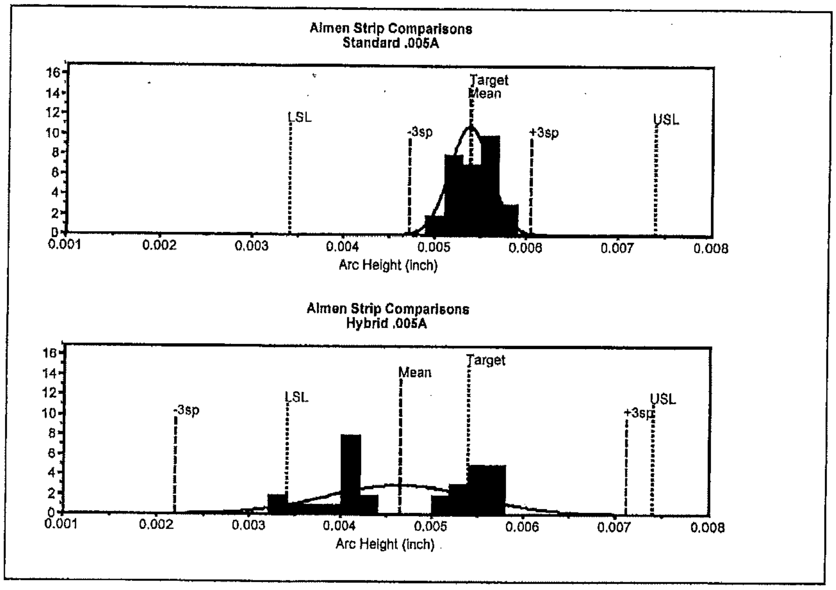


**Figure 1.** Trial 1 with CW14 media — Target intensity .0054A

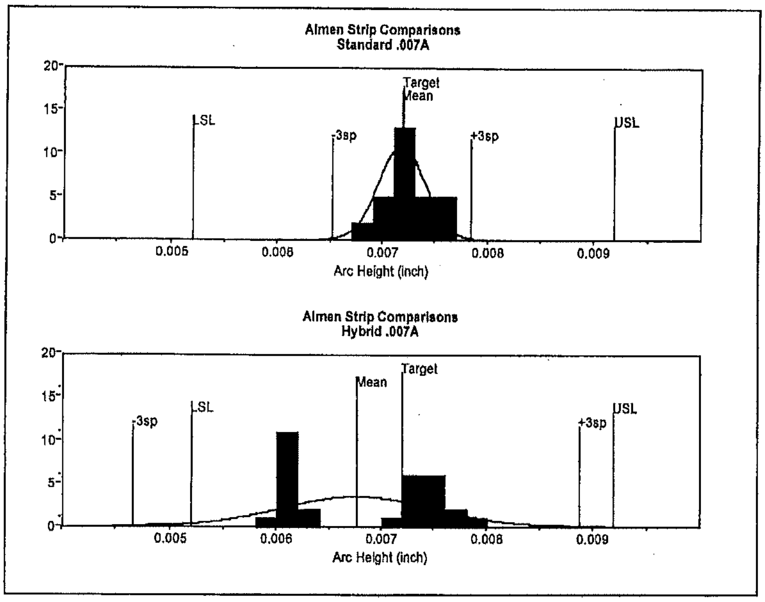


**Figure 2.** Trial 2 with S-330 media - Target intensity .0072A

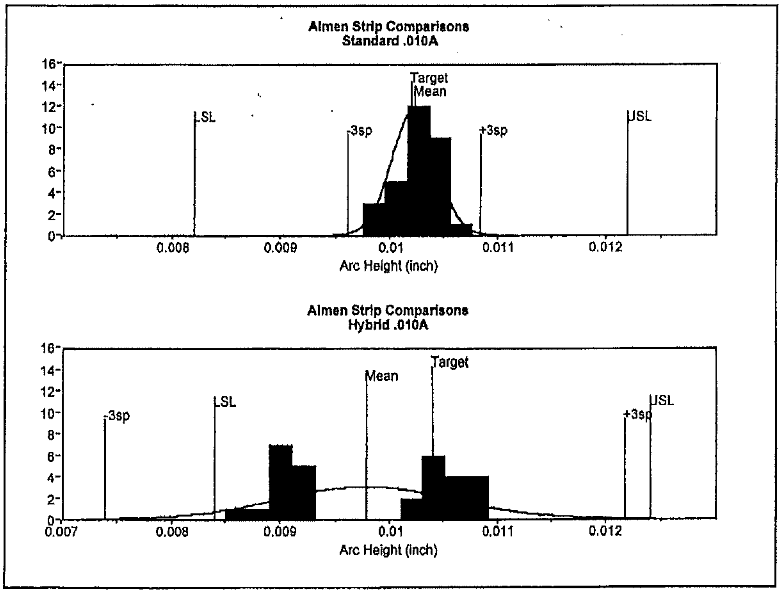


**Figure 3.** Trial 3 with CW14 media — Target intensity .0102A

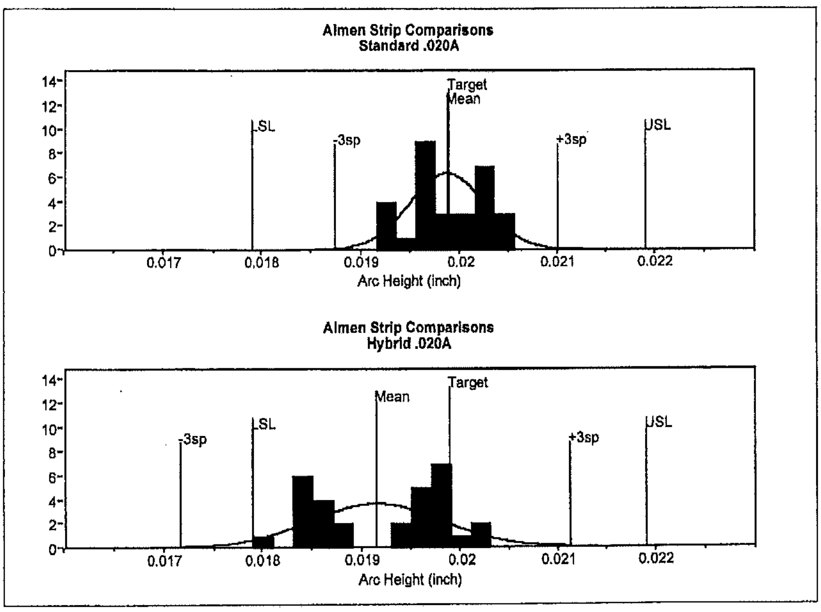


**Figure 4.** Trial 4 with S-330 media - Target intensity .0199A

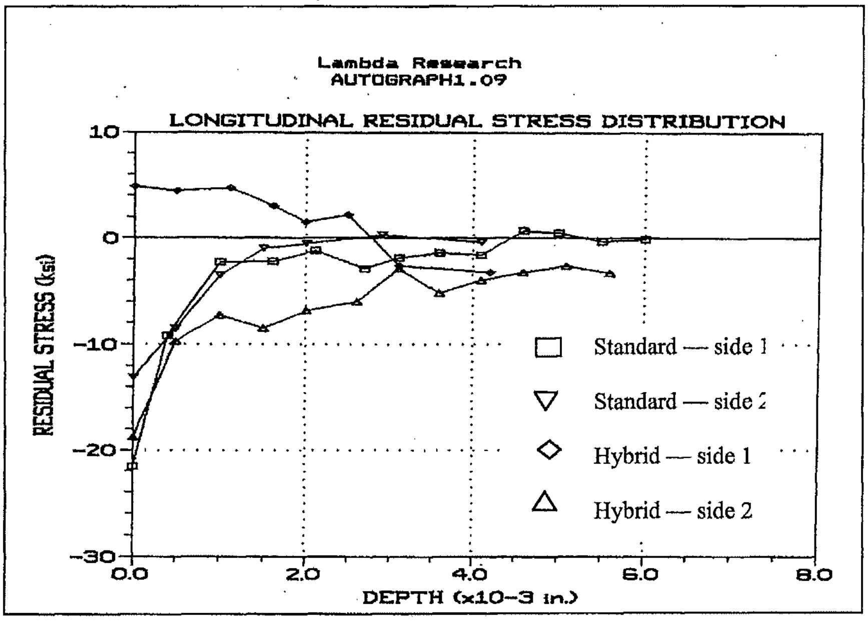


**Figure 5.** X-ray diffraction stress profiles of un-peened strips showing the stresses that exist on opposites sides of the strip. Note the tensile stresses of one side of the hybrid strip shown by the diamond symbol. ◇


## 5 Acknowledgements

The author wishes to thank Progressive Technologies in Grand Rapids for conductiong peening trials and Lambda Research in Cincinnati for conducting X-ray diffraction residual stress measurements in this project.


## 6 References


[1] SAE J442 Test Strip, Holder and Gage for Shot Peening **2001** Society of Automotive Engineers, Warrendale, PA, USA