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ALMEN GAGE ACCURACY

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Abstract

The Almen gage has been the dominant process control device for shot peening since its introduction in 1942. The ability of this gage to accurately determine shot stream intensity is related to its construction and maintenance. Attributes investigated included proper placement and wear of balls, indicator tip and guide pins, and influence of indicator tip spring force upon the Almen strip. A new calibration block, flat on one side and curved on the other to represent 0.24 inch arc height, is described.

Keywords

Almen Gage, Almen Gauge, Shot Peening, Peen Forming

Introduction

Since its introduction in the 1940's, the Almen gage has provided process control for the shot peening process. The blast stream energy is a very critical process variable and it can be measured with a small steel test strip and a test gage. The original gage design, invented by J.O. Almen, was described in his U.S. Patent Number 2,350,440 and it used two knife edges to support the test strip. One side of the test strip is exposed to the blast stream causing the strip to curve. The amount of curvature, as shown by the arc height, is a measure of the intensity of the blast stream.

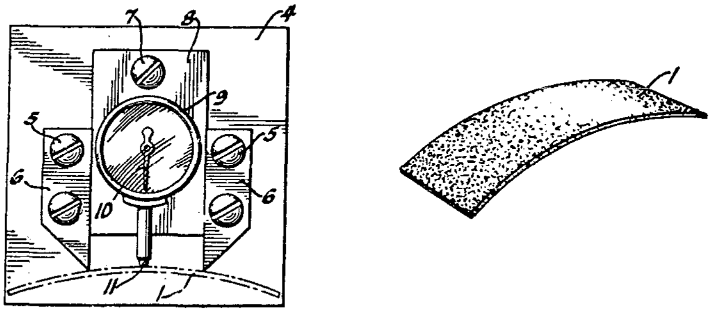


Figure 1. Original Almen Gage

This gage was later superseded by Almen Gage No. 2 which used four balls to support the strip during measurement. This approach accommodated the compound curvature exhibited by the strips (i.e., both span-wise and chord-wise curvature of the strip). For a more detailed explanation of the proper use of the Almen strip, block and gage see Society of Automotive Engineers publications J442 and J443.

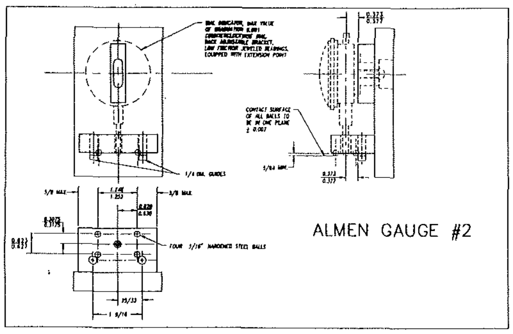


Figure 2. SAE J442 Reference Drawing

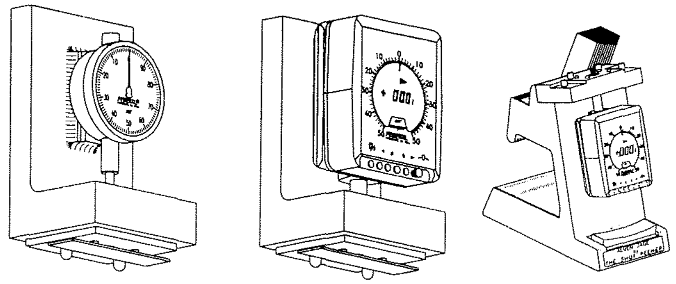
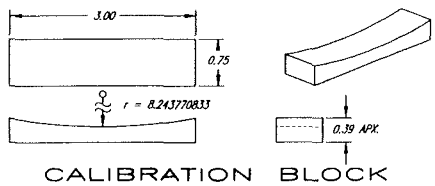


Figure 3. Modern Almen Gages

Calibration Gage Block

A special calibration block was designed to facilitate the investigation of Almen gage accuracy. The block was made by precision grinding to provide a flat surface on one side and a curved surface on the opposite side. The curvature was set to represent the shape of an Almen strip having a deflection of .024". This value was chosen because it is the maximum value expected in usage. For A-strip intensities or arc heights greater than .024" the C-strip is supposed to be used.



Arc	Radius
0.005	39.15875
0.010	19.63000
0.015	13.12208
0.020	9.86938
0.025	7.91875
0.030	6.61917
0.035	5.69161

Figure 4. Calibration Block

The calibration gage block was constructed to provide a deflection of .02400" (+/- .00001") when placed upon the Almen gage. The radius of curvature was 8.2348 inches. Curvature was provided in the span-wise direction only; there was no contribution from chord-wise curvature due to the difficulty of grinding a compound curvature block. See Appendix for mathematics.

It is interesting to note that the calibration block profile does not match the profile of a strip peened to .024". The reason for this is that the chord-wise contribution of curvature is missing from the calibration block and therefore the span-wise radius must provide all of the curvature.

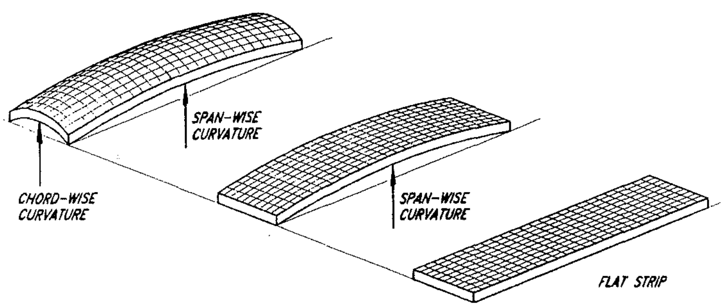


Figure 5. Strip Curvature.

The calibration gage block would not fit onto a standard Almen No. 2 gage because of this interference and the base of the gage had to be modified.

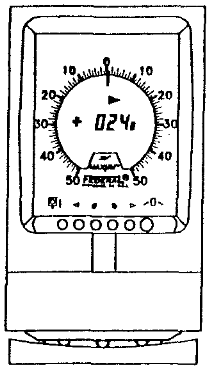


Figure 6. Almen Gage Base Modification

Investigation - Construction and Maintenance

Areas of concern regarding Almen gage accuracy are adherence to design (construction) and deterioration of components (maintenance). Unless noted otherwise all measurements refer to the calibration gage block which provides an arc height of .024". Allowable deviation refers to Almen gage construction that does not cause more than .0001" error in measurement. The drawings and dimensions shown in SAE document J442 are used for reference.

Construction

1. Indicator Accuracy
2. Support Ball Placement
3. Support Ball Plane Flatness
4. Guide Pin Placement
5. Indicator Tip Placement
6. Indicator Tip Force

1. Indicator Accuracy

The tolerance for indicator accuracy is not specified.

The accuracy of the indicator device is intuitive and doesn't need much comment. There is presently a trend to require resolution of .0001 inch when recording arc height measurements. This requirement can best be achieved by digital indicating devices if the measurement range is greater than .020 inch. Mechanical type indicators are not suited for high resolution readings over a large range.

2. Support Ball Placement

The tolerance specified for ball placement is ± .002"

The influence of ball placement was studied by calculating the error due to relocation of the balls along the span-wise axis (3 inch axis). See Appendix for mathematics.

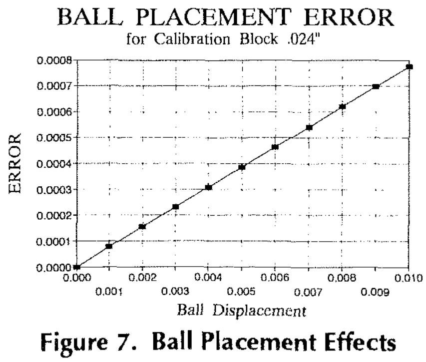


Figure 7. Ball Placement Effects

3. Support Ball Plane Flatness

The tolerance specified for ball plane flatness is ± .002"

One ball was moved to create an offset of .010" at one of the ball contact points. This action caused the flat calibration block to tilt and achieve contact with only three of the four balls. The indicator was zeroed and readings were made with the calibration block tilted in both directions. The tilting action did not change the zero reading.

The reason for this is explained by visualizing a line drawn from the offset support ball to the diagonally opposite ball and with the indicator tip at the midpoint of this line. Tilting the calibration block would allow it to rotate around this line. Since the end points of the line do not change, then the midpoint of the line will not change. Therefore the indicator tip will not change its position and the indicator reading will not change.

Note: The above analysis is valid if, and only if, the indicator tip is not flat. It must act like a point contact on the line of rotation, other wise the tilting action will show an offset.

Readings of strips peened to arc height deflections of .005, .010, .015, .020, and .025 were made with a standard specification ball plane flatness of .002" and repeated with on ball offset .010". The readings taken with the offset were not different than the standard set-up. We therefore concluded that ball plane flatness specification was not a critical factor in Almen gage accuracy.

4. Guide Pin Placement

The tolerance specified for pin placement is ± .002"

Guide pins are used to position the strip in the chord-wise direction. Investigation into the accuracy requirements for guide pin location were abandoned due to lack of knowledge of the nature of chord-wise curvature.

Two possibilities exist. Either the chord-wise curvature has a true radius, or it does not. If it does, then moving the strip along the chord-wise axis does not corrupt the reading and guide pin placement has no influence. (Assuming you keep the strip in contact with the balls.)

If the curvature is not a true radius, then indicated reading corruption could occur. But lack of data indicating deviation from a true radius prevents meaningful discussion in accuracy and tolerance requirements. More investigation is needed for this attribute.

5. Indicator Tip Placement

The tolerance specified for placement of the indicator tip is ± .005"

The influence of indicator tip placement was studied by calculating the error due to tip displacement. See Appendix for mathematics.

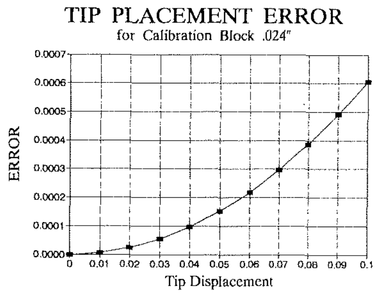


Figure 8. Indicator Tip Placement Effects

6. Indicator Tip Force

The tolerance for indicator tip force is not specified.

The extension force of the indicator tip will tend to bend the strip and might change the reading. A survey of several commercial indicators, both mechanical and digital electronic, showed the following extension tip force:

	Type	Force
(1)	mechanical	75 grams
(2)	mechanical	45 grams
(3)	digital	93 grams
(4)	digital	155 grams
(5)	digital	20 grams

The extension force necessary to deflect various types of strips by 0.0001" is shown below:

Type	Force
'A' strip	300 grams
'N' strip	50 grams
Alum 2024-T3	24 grams

(The aluminum strip is used in Plastic Media Blasting for aircraft paint removal.)

These values were obtained by using a commercial force gage and first measuring the indicator tip force and recording this value for reference. Next, the force gage was placed against the Almen strip directly opposite the indicator tip. The force exerted on the strip was increased until the indicator showed .0001" deflection. The value shown in the table is the exertion force minus the indicator reference force for a net value.

It should be apparent that the indicator tip force should be specified to be less than 50 grams force for the N-strip and less than 24 grams force for the Aluminum strip.

An additional source of measurement error can occur for gages that utilize a spring-loaded finger or holding device to maintain the test strip in contact with the balls. Two designs are popular. In one design a single finger is placed opposite the indicator tip. The force exerted by the finger counteracts the indicator tip force and minimizes unwanted strip deflection.

In another design a pair of fingers is used with each finger spanning two balls. These devices, although giving the appearance of contacting the test strip opposite the ball contact point, cannot be expected to maintain that alignment. If the resulting contact is within the ball spacing, the strip may be deflected to allow the reading to be too low. If the contacts are outside the ball spacing, the strip may be deflected to allow the reading to be too high.

A similar problem may occur when a strong magnet is placed in the base area surrounding the indicator tip. If the magnetic attraction exceeds 50 grams force, then the N-strip reading will be in error.

Maintenance

Component deterioration includes the following:
1. Indicator Tip wear
2. Ball Wear

1. Indicator Tip Wear

The tolerance for indicator tip wear is not specified.

As the indicator stem becomes flat, the indicator is not allowed to drop its full distance prior to contacting the curved strip. This gives an under-size reading.

The indicator tip radius is not specified. A survey of several Almen gages indicates that various sizes are in use, with the most common size being .125" radius. Since the equivalent radius of a strip peened to .024" arc height is over 8", then just about any tip radius would be acceptable. This would hold true as long as the tip is not worn flat. See Appendix for mathematics.

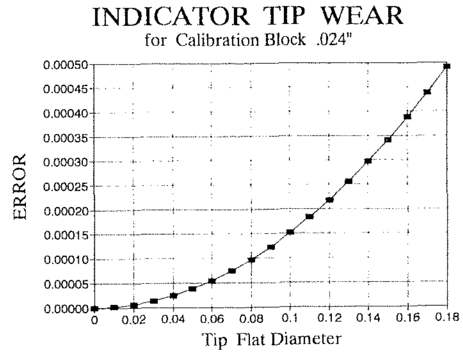


Figure 9. Indicator Tip Wear Effects

2. Ball Wear

The tolerance for ball wear is not specified.

Ball wear introduces a complex error on Almen gage accuracy. The contact point for a flat strip is at the bottom of the ball. As strip curvature increases the contact points shift, following the curvature of the ball. As the balls wear flat, the effective ball contact points for a curved strip increase their chord length. This motion effectively allows the strip to drop and gives a high reading. The degree of error depends upon the flatness of the balls and also the curvature of the strip.

The following graph was generated using Almen strips of various arc heights which were positioned on balls having various degrees of flatness.

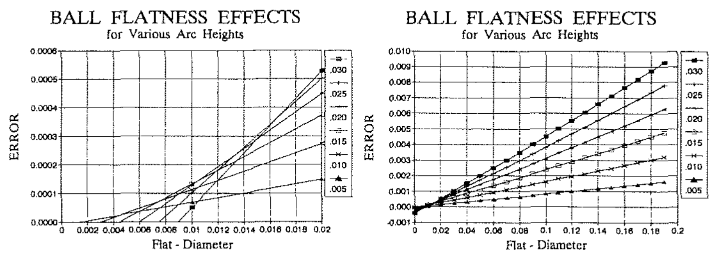


Figure 10. Ball Wear Effects

Summary

Attribute	Specification	Allowable*	Figure
Ball Placement	±.002	±.0013	7
Ball Plane Flatness	±.002	N/A	-
Guide Pin Placement	±.002	?	6
Tip Placement	±.005	±.041	8
Tip Force	None	50 grams	-
Tip Wear	None	.081" dia.	9
Ball Wear	None	.009" dia.	10

*Allowable tolerance with .0001 indicated error

Conclusion

Almen gage accuracy depends on its construction and maintenance. The manufacturer's certification should be carefully checked for new and refurbished gages. Intermediate checking can be performed with a precision calibration block. The use of a special design calibration block will check multiple aspects of the Almen gage for accuracy. Periodic re-calibration should be performed to assure continued accuracy.

For a copy of Appendix circle Bingo No. 36