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So You Think Almen Strip Coverage Is Important?

YES, IT IS, but only in a limited sense. Almen strip coverage is important in that it must be uniform because that is an implicit and necessary condition to ensure that intensity determination via a saturation curve will be correct. Otherwise, Almen strip coverage is unimportant! One of the authors, John Cammett, has published articles on the general subject of coverage in the two previous issues of this publication. The first article, *The Time Paradox in Peening*, dealt with the separate issues of Almen strip exposure time for intensity determination and part exposure time in the peening process. The second article, *Are You Peening Too Much?*, dealt with the desirability of peening to lower coverage values than is conventionally practiced, that is, 80% coverage instead of 100%. While having no intention of writing a third article on the subject, the authors decided to address specifically the issue of Almen strip coverage and its relationship to part peening coverage.

The authors assert that there is no relationship between Almen saturation time and part coverage in peening despite some peening specifications and instructions which incorrectly imply otherwise. In a sense, this article deals with the same issues as the first, but here the emphasis is different. The fundamental flaw in using Almen saturation time to represent time to full-part coverage in a peening process is that the part hardness is likely to be different from the Almen strip hardness. Thus, the part will respond to peening differently from the Almen strip in terms of coverage rate and the part coverage time will not relate to Almen saturation time even if area and geometry are compensated. Additionally, you will probably be surprised to learn that the Almen strip is generally not fully covered at the saturation time. Please read on for further supporting arguments and evidence.

PEENING LIKENED TO HARDNESS TESTING

The effect of a single piece of shot on a metal surface is much like the effect of an indenter used for testing hardness. In order to determine the hardness of a metal, a shaped indenter is driven into the surface of a work piece using a controlled force. The depth to which the indenter penetrates the surface determines the hardness. (The deeper the dent, the softer the metal.) When the indenter is removed, the impression from the indenter remains, along with the associated compressive stresses.

In the case of peening, the indenter is a media particle, hopefully spherical or nearly so, which impacts a part surface and leaves an impression of itself (dent) after rebounding. Schematically, a diametrical cross-section of a peening dent and surrounding material is shown in Figure 1. Analogously to a hardness impression, for given energy of impact and appropriate media particle properties, the dimensions of a peening dent are inversely related to the part material hardness, elastic modulus and/or plasticity-related properties. The size of the plastic zone surrounding the dent is also related to the impact energy and material properties, but it is beyond the scope of this article to attempt to relate details of this relationship. Let it suffice for current purposes to say, however, that the sizes of shot peening dents (and associated plastic zones) are inversely related to part hardness for given impact energy (intensity), media type and size.

PEENING DENT SIZE AND COVERAGE

It follows directly from the above that the sizes of shot peening dents will be different in materials of different hardness. For a given intensity, materials of lower hardness will exhibit larger dents than in those of greater hardness and vice versa. For a given rate of denting (the media impact rate), coverage which is a measure of the accumulation of dents will occur sooner when dents are larger than when they are smaller. Per SAE J442, Almen strips are required to have hardness in the range of HRC 44-50 (45-48 HRC for aerospace strips per AMS 2432). Thus, if your part hardness is different, either greater or less, from the Almen strip hardness, you could not expect coverage in the part to occur in a time similar to that in an Almen strip. Even if the part hardness is similar to the Almen strip hardness, coverage times may not be

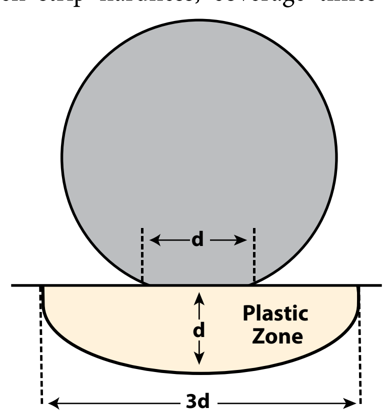

Figure 1. Schematic Illustration of Diametrical Section through a Peening Dent

equivalent if plasticity characteristics such as work hardening response and recovery are different. (Authors' note: The latter statement, though believed true, has not been verified and merits further study.)

ALMEN STRIP COVERAGE AND SATURATION TIME

A comprehensive experimental study of the time relation between Almen strip coverage and saturation time was performed by one of the authors, Jeff Derda, and reported in a poster session at ISCP11 in 2011. Test results are shown in Figure 2. The experimental details were as follows:

- Three media sizes – S330, S230, S110
- Two air pressures – 25 and 50 psi (1.72 and 3.44 bar)
- Other peening parameters: 0.36-inch (9.14 mm) nozzle diameter, 10 pound-per-minute shot flow rate (4.53 kg), 6-inch nozzle height above strips (152.4 mm), 90˚ incidence

Six sets of Almen strips (all strips from same production lot) for each given media size, air pressure and other fixed parameters were affixed in standard holders arranged on a turntable that rotated through the media stream in an equivalent manner. After peening each set of strips for one to as many as 27 revolutions, arc height versus revolutions results were analyzed via the computerized Kirk Curve Solver to determine the intensity and saturation time for each.

Strips were visually examined by the procedure in SAE J2277 to establish that full coverage (98%) had been attained in each set. Further coverage measurements were made with the Toyo Seiko Coverage Checker.

It was concluded that saturation time in a given set of strips always occurred before full coverage. The ratio of full coverage time to saturation time varied from 1.5 to 3.1 for the six sets of strips and thereby proving that there is no correlation between Almen saturation time and strip coverage. (See Figure 2.)

SUMMARY

By fundamental logic and argument regarding hardness differences, the authors established that there is no general relationship between Almen saturation time and peening coverage time for parts. Further, testing has demonstrated that even for Almen strips, there is no systematic relationship between strip saturation time and coverage.

Do you still believe that Almen strip coverage is important and that part coverage in peening should be based upon saturation time?

Test Settings: S-390, 25 PSI, 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	3.1	36
2	3	7.1	40
3	5	9.5	79
4	7	10.9	82
5	9	11.6	82
6	11	12.6	85
7	13	13.3	86
8	15	13.8	93
9	17	13.9	95
10	19	14.0	97
11	21	14.1	99

- Saturation Time: 12.3 Revolutions
- Coverage/Saturation: 1.71

Test Settings: S-390, 50 PSI, 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	8.1	49
2	3	14.4	52
3	5	17.2	61
4	7	18.8	73
5	9	20.3	81
6	11	21.0	78
7	13	21.9	84
8	15	22.5	97
9	17	23.2	89
10	19	23.4	95
11	21	23.8	94
12	23	24.1	99

- Saturation Time: 12.2 Revolutions
- Coverage/ Saturation: 1.89

Test Settings: S-230, 25 PSI, 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	4.4	28
2	3	7.4	46
3	5	8.6	86
4	7	9.1	65
5	9	9.6	73
6	11	10.1	83
7	13	10.3	95
8	15	10.5	87
9	17	10.5	85
10	19	10.6	92
11	21	10.9	93
12	23	10.9	96
13	25	10.9	94
14	27	11.1	98

- Saturation Time: 8.6 Revolutions
- Coverage/ Saturation: 3.14

XX = Measurement error caused by slightly darker strip surface.

Test Settings: S-230, 50 PSI, 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	8.6	48
2	3	12.4	67
3	5	14.0	84
4	7	14.8	89
5	9	15.3	95
6	11	15.7	96
7	13	15.9	100
8	15	16.0	98
9	17	16.2	99
10	19	16.2	100

- Saturation Time: 5.8 Revolutions
- Coverage/Saturation: 2.24

Test Settings: S-110, 25 PSI, 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	3.8	67
2	3	5.6	80
3	5	5.9	99
4	7	6.2	98
5	9	6.4	98
6	11	6.6	99

- Saturation Time: 4.1 Revolutions
- Coverage/ Saturation: 1.22

Test Settings: S-110, 50 PSI, 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	7.2	60
2	3	8.4	83
3	5	8.9	93
4	7	9.4	95
5	9	9.5	97
6	11	9.6	97
7	13	9.7	98
8	15	10	99
9	17	9.9	99

- Saturation Time: 1.4 Revolutions
- Coverage/ Saturation: 9.29

Figure 2. Test results from "Time Relationship Between Saturation and Coverage" study