History of Shot Peening Specifications

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ABSTRACT

The history of shot peening specifications is presented in a chronological format with prelude of situations existing in 1940. The specifications cited are of US origin and in the public domain (i.e. no proprietary specifications such as GE or Boeing are cited). Some specifications relating to media have been excluded for brevity.

SUBJECT INDEX

History, Specifications

INTRODUCTION

Early application of shot peening in the 1930's and 1940's relied upon proprietary specifications, primarily from General Motors. Efforts to improve fatigue life of critical aircraft components for World War 2 resulted in creation of specifications by the US Army, Navy and Air Force and also Society of Automotive Engineers. The data is presented in chronological sequence to establish a time-line of events.

PRELUDE:

1940	Zimmerly of Associated Spring (Barnes-Gibson-Raymond Division) wrote an article in 1940 for the 22nd annual convention of ASM entitled "How Shot Blasting Increases Fatigue Life". He stresses the time of shot blasting is important (coverage) and also shows that heating above 500 degrees F will diminish the beneficial effects of the treatment. (1940000.pdf)
1941	In a subsequent article a year later Zimmerly writes: "Shot Blasting and its Effect on Fatigue Life" he mentions the lack of control of the process and suggests that some type of control could be used *"The inclusion of a standard test piece in the parts being blasted would form an empirical check upon the process."* (1941006.pdf)
1942	A year after that, in 1942, J.O. Almen, working for General Motors, makes application for a US patent which describes the first use of a test strip, holder and gage. The gage, using two knife edges to support the strip, measured the convex curvature of a blasted piece of spring steel "slightly less than .050 inch thick". Other than describing that the curvature is a reflection of the intensity of the shot blast there is no mention of a definitive method to be used to provide consistent process control. (1944011.pdf)
1943	A few months later, in November of 1943, a General Motors document, drawing No. S-200-7, shows a revised gage design referred to as #2 Gage which uses 4-ball support instead of knife edges to recognize the compound curvature of the test strip. When Almen's patent finally issues in June of 1944, it is already obsolete. (1945002.pdf)

1943	Almen describes the merits of his shot blasting test methods in an article "Shot Blasting to Increase Fatigue Resistance" published in July of 1943 in SAE Journal Vol 51 No. 7. The article shows the test strip as mounted on the holder and his special gage to measure its curvature. The test strip is subjected to the shot blast in the same manner as the part being peened. There is no mention of use of a saturation curve. Later, Almen writes in 1943 for Metal Progress Magazine "Peened Surfaces Improve Endurance of Machine Parts" and he shows a flat test strip of tempered (stress free) steel held down to stiff block by screws so only one surface is exposed to cold working. He also shows the dial gage and knife edges for measuring curvature on the test strip. (1943003.pdf)
1945	General Motors then makes additional refinement of process control in a memorandum report S-200-9C written in 1945 by R. L. Mattson and H. E. Fonda of Research Laboratories Division, entitled "Peening Intensity Measurement". It introduces the concept using a series of test strips, each for a different exposure time. The Almen #1 gage is not to be used since it has been superseded by the Almen No. 2 gage. A drawing dated 11-23-1943 shows the standardized dimensions of the gage. A correlation chart between the #1 and the #2 gage is included for reference. It is interesting to note how the Almen strip quality was to be controlled. The material specification is purposely omitted because the method of rolling and possibly other factors may influence the response of the strip to the blast of shot. It is considered more dependable to approve separately each source of supply. From 5 to 12 test points were deemed necessary to construct the intensity curve. *"The gage reading corresponding with the point A where the curve flattens out is taken to be the intensity of the particular blast."* Furthermore, the "C" strip is to be used for intensities above .024A. There is no mention of a "B" strip or indication of why the letters "A" and "C" have been chosen. (1945002.pdf)
1949	The recognition of the benefits of stress peening, mechanically stressing a part during the peening operation, is discussed by Straub and May in article published by The Iron Age magazine, April 21, 1949. Since this imparts a much deeper compressive stress later specifications emphasized that stress peening was not to be used unless authorized. (1949003.pdf)
1960	H. J. Noble of Pratt & Whitney Aircraft publishes article "An Evaluation of Fine Particle Abrasive Blasting and Other Methods of Surface Improvement" wherein he introduces the more sensitive "N" strip with approximately the same ratio of response to the "A" strip as between the "A" strip and the "C" strip, which is ratio of 3½. (1960002.pdf)

CHRONOLOGY:

1944	The Ordinance Department of the U S Army, in August of 1944, circulates a tentative specification AXS-1272 titled "Shot Peening of Metals, General Specification For". It carries the notation *"This specification covers shot peening of metal parts for the purpose of increasing the endurance limit of the part."* Only five sizes of shot are recognized and they are qualified by use of four sieves for each size. Up to 10% of the shot in use may be sub-standard. It does discuss process control by saying: *"The shot peening intensity shall be determined by subjection of one side of a flat steel strip to the shot peening procedure used in production. The magnitude of the curvature of the strip after treatment measures the shot peening intensity. For intensities in the designation of which the letter "A" appears the test strip shown in Figure 1 shall be used. For intensities in the designation of which the letter "C" appears, the strip shown in Figure 2 shall be used."* The gage depicted is the #2 gage developed by General Motors in 1943. Intensity is evaluated as the point on the curve where it flattens out. The following discussion on coverage introduces the mixing of concepts, namely visual examination of the peened surface in one method and then another method of observing the saturation of the Almen strip. *"The time of exposure should give complete coverage. The coverage is frequently gaged by eye. A more reliable method is to expose a series of test strips for varying lengths of time under a given set of shot peening conditions, then plot a curve of gage reading against time of exposure. The curve should flatten off at a time which gives complete coverage."* (author's note: This coverage concept was probably relevant since the Almen strip and automotive components (valve coil springs) were of similar steel alloy and hardness.)
1949	MIL-G-851 (Ships) is issued by US Navy to describe Metal Grit and Shot for Blast Cleaning and Peening. This is later (1950) renamed MIL-M-851 and then (1965) MIL-S-851.
1948	The Society of Automotive Engineers, SAE, introduces aerospace materials specification AMS 2430 on September 1, 1948. Its preamble states: *"Application: To impose compressive stresses on specified surface layers of metallic parts, primarily for increasing fatigue strength* but may be used for other purposes such as testing for bond of plated materials." The "A" strip is to be used for intensities up to .020 inch then the "C" strip is to be used. Both Almen Gage No. 1 and Almen Gage No. 2 are described but preference is given to Almen Gage No. 2. Test specimens shall be included with every batch of parts during peening, or at the beginning of each production run and at intervals not longer than every four hours thereafter for continuous peening, or at other intervals as stipulated by the purchaser. Such specimens shall show an intensity within the range specified for the parts." And, *"The time, the shot, the shot velocity, the positioning of the parts which will produce satisfactory peening intensity on the part shall be established, and the test specimen described in 4.4 shall be used to control the required conditions in production. The specimens to be peened shall be attached to suitable blocks or fixtures or pilot parts in such a position as best to represent production parts to be peened."* Also, *"Unless otherwise specified,*

	variation from the specified peening intensity shall be -0 to +5 (-0.000 to + 0.005 in. arc height)."
1952	The first specification to control the dimensions and attributes of the strip and gage is by SAE in document J442 published in January 1952. It has specifications for material as SAE 1070 cold-rolled string steel with square edge No. 1 (on 3-in. edges) with blue temper or bright finish uniformly hardened and tempered to HRc of 44-50. Flatness is ±.0015-in. arc height as measured on standard #2 gage. Three intensity determinations are to be made each (work) shift.
1952	A companion document, SAE J443 "Procedures for Using Standard Shot-Peening Test Strip published in January 1952 states *"The gage reading corresponding with the point A where the curve flattens out is generally taken as the measurement of the intensity of that particular peening. In some cases, this point is difficult to pick out and requires some judgment."*
1953	MIL-S-13165 (ORD) (author's note: I have not found copy of this document.)
1961	A revision to J442 published in June of 1961 introduces the "N" strip and reduces the flatness tolerance to ±0.001-in for the "A" strip and leaves the tolerance at ±0.015-in for the "C" strip.
1972	MIL-R-81841 (AS) "Rotary Flap Peening of Metal Parts" is introduced by government. Developed in cooperation with 3M Corporation to provide a portable peening system suitable for in situ applications, primarily helicopter repair.
1972	MIL-W-81840 (AS) "Wheels, Peening, Rotary Flap" describes equipment requirements to meet MIL-R-81841.
1974	MIL-P-81985 "Peening of Metals" introduced by government to meet needs and objectives of Naval Air Systems Command. It includes media requirements as well as qualifications of peening operators.
1984	January 1984 J443 describes *"Saturation has been attained when the "knee" of the curve is passed and increasingly longer periods of peening time are required for a measurable increase in test strip arc height. The location of the knee, point A shown in Figure 1, can be defined as that point on the curve beyond which the arc height does not increase more than "X" percent when the peening time is doubled. An arc height increase of 20% for doubled peening time may be adequate for some applications. An increase of 10% for doubled peening time defines the knee for critical applications. A smaller percentage increase than 10% requires longer peening time to reach this "knee" in the curve."*

1987	US Navy introduces LPS/JX 341-149-87 "Peening of Metal Parts Local Process Specification". This document is self-contained including all requirements for strips, holder, gage, media size and shape. It includes the 10% rule but then refers to it as criteria for full coverage. It goes further in establishing peening coverage time as a ratio of area of Almen strip to area to be peened.
1988	SAE AMS 2431 publishes "Peening Media, General Requirements" as a collection of individual documents for various media types.
1990	SAE 2432 was first issued in 1990. Strip attributes referred to J442 except thickness and flatness tolerance is ±0.0005 inch and hardness 45-48 HRc for A and C strips and 73.0-74.5 HRa for N strips. Gages to have accuracy of ±0.0001 inch. and must be able to read thickness of Almen strips. A flat gage block is mentioned but without requirements. Sub-size strips are allowable. (author's note: The strips referenced in J442 are described with metric dimensions but AMS 2432 alters the tolerance using inch dimensions.) Media is to comply with SAE AMS 2431.
1990	NAVAIR Instruction 48.70.2 establishes requirement that AMS 2432 must be used for aircraft components during rework repair format.
1995	US Navy introduces LPS 500 "Peening of Metal Parts". This document is self-contained including all requirements of strips, holder, gage and media size and shape. It includes written and practical examination for operator qualification.
1997	SAE introduces AMS-S-13165, "Shot Peening of Metals" as a verbatim successor to MIL-S-13165. This is part of the government regulation reduction program to encourage industry to develop and maintain specifications.
1998	MIL-S-13165C is cancelled by the government and users are directed to AMS-S-13165 as a suitable replacement.
2000	SAE introduces J2441 "Shot Peening" which is similar to MIL-S-13165 but with relaxed requirements for media using the SAE "J" series of media.
2001	SAE introduces AMS-R-81841 "Rotary Flap Peening of Metal Parts" as a verbatim successor to MIL-R-81841.
2003	SAE introduces J2277 "Shot Peening Coverage" to emphasize that coverage is independent of Almen strip performance.
2003	J443 is revised to by removing discussions of coverage.
2003	SAE cancels AMS-R-81841 to avoid confusion with the Department of Navy. (author's note: apparently the Navy never abandoned the spec but it was nevertheless adopted by SAE)

DISCUSSION

The evolution of peening specifications reveals a desire to control the process and an appreciation of the benefits to be derived from peening but a major difficulty is introduced early with control of peening coverage. While coverage is almost always referred to as complete denting of the surface it was also related to the "saturation point" on the Almen strip response curve, often labeled "full coverage point".

Intensity of peening was initially described as the point on the Almen strip saturation curve where it "flattens out". This was often accompanied with a notation that this can be difficult to determine and some judgment may be required. The concept of assigning a numerical value to saturation using the 10% rule was introduced in 1984.

SAE Surface Enhancement Division of Fatigue Design and Evaluation Committee eventually created an entirely separate document for peening coverage to emphasize that coverage is not related to Almen strip performance.

CONCLUSION

The proliferation of so many specifications suggests that there is little consensus on appropriate process control. SAE had endeavored to make AMS 2430, the earliest recorded peening specification, an acceptable replacement for AMS-S-13165 but several issues of technical equivalence impede the transition. It appears that both specifications will continue as separate and active requirements.

ACKNOWLEDGMENTS

All of the research material for this project has come from the library of Electronics Inc. and most of it is available on-line at shotpeener.com

REFERENCES

References cited are accessible at shotpeener.com in pdf format. SAE documents may be obtained at SAE.org