AN INSIDER'S PERSPECTIVE
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Are You Still Using MIL-S-13165?

INTRODUCTION

We have been shot peeners for a while now. Having fully acknowledged the efficacy of the process, we have advanced it from hammer peening leaf springs in medieval times to today's computerised shot peening of mission-critical aircraft components. Over the years, along with sophisticated machinery, we have also installed processes and specifications that ensure process reliability. We have early adopters in the automotive and aerospace industries, followed by oil & gas, mining, and medical implants embracing our cohort more recently. Though the common goal is to generate compressive stress leading to increased fatigue life, the indentations also create reservoirs that store the lubricant in certain components. Whatever the ultimate goal, clear awareness of the process and the desire to adopt are directly proportional to the user's earnestness in conforming to commonly adopted specifications.

In my involvement with this industry over the last three decades, the most common document cited to me is MIL-S-13165C. For those new to shot peening, MIL stands for Military, and the first version of this specification, "Shot Peening of Ferrous Metal Parts" was published in December 1953. It was intended for use by Departments of Army, Navy, and the Air Force. This specification was cancelled in February 1998 and replaced by AMS-S-13165. AMS-S-13165 was made redundant by AMS 2430 and AMS 2432. We now reference and conform to AMS 2430 and AMS 2432.

Our discussion here is driven by the fact that several end-users continue to use the original MIL specification for their peening operations. To those users, I hope to provide a comparison and plausible reason to progress to a common spec platform.

HISTORY

(Author's note: I received documentation and consultative assistance from Jack Champaigne, Chair of the Surface Enhancement Committee, SAE, on the history of specifications.)

AXS-1272 - General Specification for Shot Peening of Metals was drafted and revised in August 1944 and it is considered the foundation for the MIL spec. This document was created by the Ordnance Department of the US Army and has all the fundamental information required to conduct shot peening, such as intensity, shot size, shot maintenance, coverage, and intensity (saturation curves did not exist during those times, and what we know as "arc height" today was referred to as "intensity" in this specification). The specification also lists the criteria for shot selection. Interestingly, in giving more importance to coverage, the specification suggests plotting a saturation curve with test strips at increasing exposure times and relying on flattening of this curve as a measure of complete coverage. In 1944, Almen strips were sold by Pangborn and Wheelabrator (formerly American Foundry Equipment Company), two of our industry's oldest companies, per this document.

MIL-S-13165 was published and progressed to four updates, starting with MIL-S-13165 (ord) in December 1953, followed by MIL-S-13165A in March 1956, MIL-S-13165B in December 1966 and finally MIL-S-13165C in June 1989. Overall, the MIL spec is an extension or replacement document to AXS-1272. Salient points from each update of the MIL spec are listed here to demonstrate the progression:

- The media types listed in MIL-S-13165A are cast iron, cast steel, and cut wire (conditioned). Arc heights were still an acceptable measure of intensity. These "intensity" values were measured using the A and C strips only; the N strip did not exist. There was no quantifiable number to signify complete coverage (such as 98% or 100% as we know now).
- Though some of the details such as arc height/intensity still prevailed, MIL-S-13165B is a quantum leap from its previous version. Some of the notables include:
    - Type of equipment and requirement of separator for continuous removal of broken or defective shot
    - Introduction of the N strip
    - Listing of minimum shot sizes for a particular intensity target (details were likely not available in part drawings at that time)
    - Better definition of strip limitations for intensity ranges
    - Acceptable and unacceptable shapes of shot (this is the first instance where shape of the shot is given importance in a specification)

Given that the MIL spec remained unaltered for the next 23 years, the final version MIL-S-13165C published in June 1989 had substantial changes. If you read it now, this version might still seem outdated in comparison to AMS 2430 and

2432. However, MIL-S-13165C embodied sound peening practices that were further polished and clarified, with the benefit of experience, in the AMS documents listed above.

MIL-S-13165C was cancelled in February 1998 and replaced with AMS-S-13165. This AMS document, with some editorial changes, signified the transfer of this spec from the Military to AMS (Aerospace Material Specification) administered by SAE (Society of Automotive Engineers). This transformed the specification to an industrial rather than a military standard.

MIL-S-13165C – THE MIL SPEC

During its active life, the MIL spec widely proliferated in the shot peening industry. It is still common for users to seek its conformance in their peening operation. The Aerospace industry, with its multi-tiered structure, has almost entirely switched to AMS 2430 and 2432. Other industries, including part of the Automotive sector, still use MIL-S-13165C. These are some of the features of MIL-S-13165C that keep it relevant to a large group of users:

- **3.2:** Introduction to Automated and Computer controlled shot peening—not only does the specification account for varying levels of sophistication in peening equipment types, it also introduces the user to process control elements, shutdown limits and reporting of process data. These details that are elements of AMS 2430 & 2432 were novel in 1989 when revision C was published.
- **3.3.6:** In addition to suggesting intensity values based on part thickness when the intensity is not listed, the specification provided an allowance of -0, +30%, but in no case less than three intensity units, when only a minimum intensity is specified. This removes the ambiguity in situations where the engineer drafting the peening requirements failed to accommodate for the practical difficulty (and futility) in achieving a fixed intensity value, especially at multiple locations in a component.
    - An interesting comment was made by Walter Beach of Peening Technologies who helped me review this article. He noted that a major aerospace company permits a default tolerance band of -0.002" to +0.005", unless otherwise stated in the drawing. Having a wider range to start with makes it more practical to center the process.
    - When verifying the intensity during regular production (after developing the initial saturation curves), SAE J443 requires that the arc height at each strip location be within 0.0015". However, the resultant arc height does not have to be within the intensity tolerance band for verification time T.
    - AMS 2430 takes this further and attaches another condition to verification: The resulting verification arc height, along with the 0.0015" tolerance, shall stay within the intensity range for the part. MIL-S-13165 does not have this repeatability requirement.
- **3.3.9:** Media maintenance consumes a large part of the text in new and old specifications for shot peening. Notwithstanding the fact that media does play a critical role in the achievement of accurate and repeatable peening results, the different types of media validate the need for this elaboration. As a side note, all versions of the MIL spec included cast iron as a peening media type. Cast iron constitutes alloys with a carbon content greater than 2% and is not considered suitable for shot peening due to the inherent brittleness and reduced durability (i.e., its inability to maintain sphericity due to rapid fracture). Cast steel that is commonly used as a shot peening media has carbon content between 0.8% and 1.2%, thereby providing a working balance between durability and energy transmitting properties.
- **4.2.3:** Generation of a saturation curve is explained in detail in this version of MIL spec. Being the first attempt of this kind in a specification, the language (which was refined in the future AMS documents) resulted in ambiguity among its adopters. To quote, "Saturation is achieved when, as the exposure time for the test strips is doubled, the arc height does not increase by more than 10%." This was tightened to "intensity is defined as the arc height value on the curve that increases by 10% when the exposure time is doubled" in SAE J443. AMS 2430 and 2432 refer to this practice.
- The "Notes" section of this specification is filled with valuable information on the practical aspects of the process such as explaining the effect of process parameters that affect peening results (6.9) and detailed information on inspection of coverage.

It is not surprising that MIL-S-13165C was the definitive document from 1989 to 1998. It was only when the military decided to pass on the responsibility of spec maintenance to industry that the AMS peening specifications gained momentum. The original AMS document on shot peening (AMS 2430) was first issued in 1948 but not as widely used as the MIL spec for peening.

The above historical information will help answer some important questions: Can I continue to use the MIL spec? What are the differences between MIL13165C and AMS 2430/2432? What can I do if my organization insists on staying with MIL-S-13165C? Am I peening my product correctly to derive its benefits in a repeatable fashion? Let us analyze the above in the following paragraphs.

AMS 2430 AND MIL-S-13165C

The MIL spec is a standalone, comprehensive document that incorporates all required information in a single location. The AMS documents refer to multiple J documents, called "Recommended Practices." AMS 2430 is for Shot Peening, Automatic and AMS 2432 covers Shot Peening, Computer Monitored. Since the immediate correlation to MIL-S-13165C is with AMS 2430, let us compare the contents of the two documents.

- AMS 2430 has a legacy provision, where cancelled documents such as AMS 13165 can be used until such time that AMS develops a document for such processes, such as barrel peening, as long as it is approved by the purchaser.
- Maintenance of peening media is where majority of the changes appear between the documents. The following table lists those differences.

MIL 13165 C dated 7 June 1989 Shot Peening of Metal Parts	AMS 2430, Rev S, issued July 2012 Shot Peening, Automatic
3.1: Shot • (3.1.1): Cast iron is listed as one of the media types. Selection of shot hardness is explained in relation to part tensile strength. J documents are referred to for use of Ceramic and Glass bead 3.1: Shot • (3.1.1): Cast iron is listed as one of the media types. Selection of shot hardness is explained in relation to part tensile strength. J documents are referred to for use of Ceramic and Glass bead • (3.1.2): Size and quality (new or reclassified) of shot at the option of the contractor. The media should conform to: (3.1.3) - Table 1: Shape classification table • Maximum allowable unacceptable particles (shape) are greater (signified by sketches of 'acceptable' and 'unacceptable'. No definition for 'marginal' as in AMS 2430 (new and in-process)	3.1: Peening Media • Split into 3.1.1: New media and 3.1.2: In-process media • New media to conform to AMS 2431, which in turn references AMS 2431/1 to /8 for different media types and SAE/ASTM documents related to media classification and testing. These documents list the requirements for screening, acceptable shapes, chemistry etc. • In-process media (3.1.2) has screening tolerance (Table 1), acceptable shape notification (Figure 1) and shape tolerance for metallic and non-metallic media (tables 2A and 2B) • Screening (size) tolerance is identical in both specifications. • Provision for 'Marginal' shapes in specifications. Tolerance is tighter than MIL for unacceptable particles.

	Max. Unacceptable		AMS (new)	
	MIL-S-13165	AMS (in process)	Marginal	Unacceptable
S230	32	14	14	5
S280	23	9	20	4
S330	16	7	14	3
S390	45	22	39	7
S460	32	16	28	5
S550	22	9	20	4
S660	16	7	16	3

In order to conform to the stringent media quality requirements, AMS 2430 emphasizes the need for process control components such as inline classifiers and spiral separators (3.2.1.2). Though the language in the document could be interpreted as if the user is offered a choice (Equipment "may" include a media separator to mechanically control size and shape...........inclined belt), experience would have already confirmed to you that a shot peening operation can not produce repeatable results in the absence of such devices in your machine. That said, 4.2.2, Table 6 in AMS 2430 lists the frequency requirements of in-process media size and shape inspection with and without a separator.

AMS 2430 continues with other aspects of the peening process such as low air pressure alarm (3.2.1.3) for compressed air machines. Overall, AMS 2430 describes all aspects of process control and inspection in greater detail than MIL, whether it be in the main body of the specification or the comprehensive notes section of the specification.

The requirement governing an analogous parameter to air pressure, in a centrifugal wheel machine, the wheel speed, is listed in AMS 2432.

When compared to AMS 2430, AMS 2432 is extremely process-control oriented with shut-down limits imposed on critical process parameters, including the material handling equipment presenting the component to the blast nozzles or wheels. A review of AMS 2432 will require a separate discussion, outside the purview of this one.

SUMMARY

When you have a well-established peening process that conforms to MIL-S-13165C, is there a reason to adopt a different specification? The response depends on your peening equipment. If your end-customer stipulates this requirement, you could make a case with the above comparison/equivalence data. If your peening machine is built with process control components that allow meeting the requirements of AMS 2430, it might just be a matter of conducting an audit to 2430 and see how you fare. It might be as simple as making slight modifications to your process to achieve conformance. Will such conformance change the quality of your product? The answer to that question is highly subjective. There is no doubt that a tighter process will result in greater repeatability and less rejections and failures. However, that does not diminish the fact that your process can be fine-tuned by conscious choice and not necessarily dictated by a specification.