	MATERIAL PROCESS STANDARD	NO: MS-10001
		REV: C
TITLE: Directed Shot Peening of Heat Treated Gears		DATE: 14 May 2009
		PAGE: Page 1 of 8

ORIGINATED BY:	FINAL APPROVAL:
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1.0 PURPOSE:

1.1 To establish detailed requirements for developing and maintaining the effectiveness of air nozzle type directed shot peening. This process is intended to enhance the fatigue strength of heat treated gears by creating residual compressive stresses in the gear tooth root location.

2.0 SCOPE:

2.1 This standard applies to AAM outsourced and in-house shot peening. This document defines requirements that supplement engineering drawing requirements.

3.0 REFERENCE:

3.1 Engineering Blue Print Specifications
3.2 AAM-2-031 Materials Specifications
3.3 SAE J441 Cut Wire Shot
3.4 SAE J442 Test Strip, Holder and Gage for Shot Peening
3.5 SAE J443 Procedures for using Standard Shot Peening Test Strip
3.6 SAE J445 Metallic Shot and Grit Mechanical Testing.
3.7 SAE AMS 2430N Shot Peening, Automatic
3.8 SAE J2277 Shot Peening Coverage

4.0 PROCEDURE:

4.1 GENERAL

4.1.1 No changes shall be made to the shot peening process once approved and agreed upon, without a written request and without prior written approval by the Metallurgical Manager or his delegate at the receiving plant and the functional manager of Metallurgy & Materials Engineering at AAM.

4.2 RECEIVING MATERIAL

4.2.1 AAM is responsible for delivering clean, dry parts in order to minimize contamination of the shot media and to have parts suitable for shot peening.

4.2.2 All material sent to an outside processor shall be segregated and identified.

4.2.3 Material shall be staged so that it is processed on a first in, first out basis.

4.3 SPECIFICATIONS

4.3.1 Engineering Drawing Callout:

Gears that require shot peening for durability enhancement will have this specification called out on the engineering drawing. Additionally, the call out will include the Method type as listed in Table 1 and the shot size to be used.

4.3.2 The specific process and component requirements for the shot peen method type listed on the engineering drawing are in Table 1.

		METHOD A			METHOD B		
Shot Peen Process Requirements	**Shot Peen Standard**	SAE AMS 2430N (items in this spec supplement the SAE standard)			SAE AMS 2430N (items in this spec supplement the SAE standard)		
	Shot Type	SAE J441 Conditioned cut wire			SAE J441 Conditioned cut wire		
	Shot Size SAE J441	**CCW 20**	**CCW 28**	**CCW 32**	**CCW 20**	**CCW 28**	**CCW 32**
	Shot Hardness (HRC)	55-63	55-63	55-63	55-63	55-63	55-63
	Intensity of Peen Process	0.20-0.40 mm (.008-.016 ") Almen A	0.35-0.55 mm (.014 -.022 ") Almen A	0.40-0.60 mm (.016-.024 ") Almen A	0.20-0.40 mm (.008-.016 ") Almen A	0.35-0.55 mm (.014 -.022 ") Almen A	0.40-0.60 mm (.016-.024 ") Almen A
	Broken Shot (allowed in process)	5% max.			5% max.		
Shot Peened Component Requirements	**Part Compressive Residual Stress**	**-140 ksi min.** @ any point between 0.002-0.003" (.051-.076 mm) depth below surface.			**-180 ksi min.** @ any point between 0.002-0.003" (.051-.076 mm) depth below surface.		
	Part Peen Time	To be developed for individual part numbers to meet residual stress requirement.			To be developed for individual part numbers to meet residual stress requirement.		
	Process Arc Height – mm. (Almen A)	To be developed for individual part numbers to meet residual stress requirement.			To be developed for individual part numbers to meet residual stress requirement.		
	Area of gear tooth to be shot peened	Shot to be directed at drive side tooth root fillet with complete coverage from heel to toe.			Shot to be directed at drive side tooth root fillet with complete coverage from heel to toe.		
	Coverage (area to be peened)	100% min.			100% min.		

Table 1. Shot Peening Process Parameters and Component Requirements

4.3.3 Component Shot Peen Process Sheet

4.3.3.1 The shot peen process must be developed for each component to meet the residual stress requirements per the specified Method from table 1.

4.3.3.2 The Manufacturing plant Metallurgy Department is to create a Shot Peen Process Sheet for each component or component family that is peened. An example of this process sheet is in the appendix of this specification.

4.3.4 SHOT TYPE

4.3.4.1 The shot type shall be as specified in table 1 in accordance with the method identified on the engineering drawing.

4.3.4.2 The shot manufacturer must be approved by the AAM receiving plant Metallurgy Department.

4.3.4.3 The shot manufacturer shall certify all shot to SAE J441 requirements. The certification must be supplied with each batch manufactured.

4.3.5 SHOT SIZE & SHAPE

4.3.5.1 The shot size will be included along with the shot peen method on the engineering drawing.

4.3.5.2 The nominal diameter of the shot shall be less than or equal to ½ the gear root (fillet) radius. The shot size used for a component is chosen from table 1 and must meet this criteria. Any deviations must be approved by AAM Corporate Materials Engineering.

4.3.5.3 The shot size uniformity during processing must meet the requirements listed in Aerospace Material Spec AMS 2430N for Sieve testing. The process shot is to be audited and inspected per section 4.4 of this specification.

4.3.5.4 The shot shape shall be 95% spheroidal with a maximum of 5% broken particles. Production equipment must be capable of continuously screening the shot and filtering out broken particles, fines and contamination in order to maintain conformance for shot size and shape.

4.3.6 SHOT HARDNESS

4.3.6.1 The microhardness of 90% of the shot shall meet the requirement as listed in table 1.

4.3.6.2 Shot particles to be checked for hardness are to be mounted, ground and polished to the centerline.

4.3.6.3 The shot hardness must be audited and inspected per section 4.4.

4.3.7 ALMEN TEST STRIPS, HOLDER and GAGE

4.3.7.1 The Almen test strips, test strip holders and gage must conform to SAE J442 specification. The re-use of test strips in not allowed.

4.3.7.2 The type of test strip (A, C or N) depends on the intensity needed for the process. AAM parts typically use "A" test strips but "C" may be needed for intensities above 0.61mm on the "A" strip.

4.3.7.3 The Almen test strip holder must be incorporated into a fixture preferably made from a representative part being peened. The fixture must position the test strip in the area representing the surface to be peened.

4.3.7.4 Each part number being peened will have developed peen process parameters (peen time, peen air nozzle pressure, etc.) and an established process intensity that is determined using the Almen strip holder for that part.

4.3.8 INTENSITY

Shot Intensity is a measure of the impact energy striking the gear from the shot. It is a function of the shot size, shot mass and shot velocity.

4.3.8.1 The intensity range of the peening process for each component or application is defined in table 1 of this specification.

4.3.8.2 The intensity shall be controlled by a consistent and repeatable process.

4.3.8.3 To determine the intensity of the process setup, a series of Almen strips are to be processed keeping all parameters constant while varying exposure time to create an Almen saturation curve per SAE J443. See Figure 1 of this specification.

4.3.8.4 The saturation curve establishes the actual intensity for the particular machine setup. The Almen arc height is defined as "intensity" when saturation is achieved on the Almen strip which is the **earliest point on the curve where doubling the exposure time produces no more than a ten percent increase in arc height**. See Figure 1.

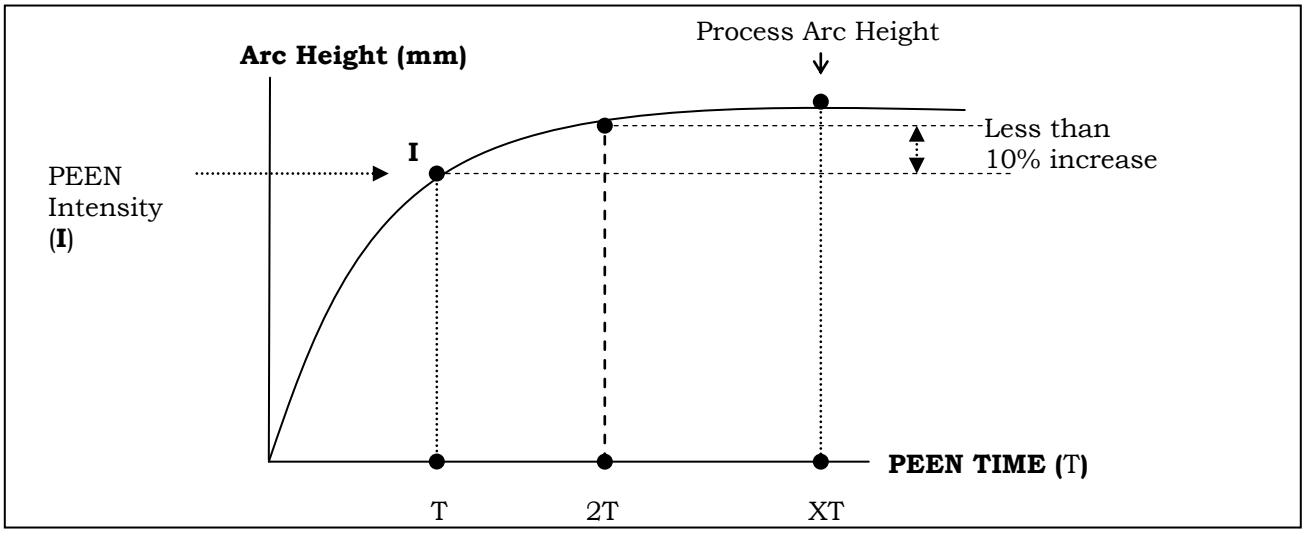


Figure 1. Saturation Curve

4.3.8.5 The saturation curve developed for the process is to be documented for each component part number and attached to the Shot Peen Process Sheet.

4.3.9 PROCESS ARC HEIGHT

4.3.9.1 Almen test strips shall be used to measure the process arc height.

4.3.9.2 The strip shall be fixtured in a position representative of the part being peened—parallel at the tooth root.

4.3.9.3 The exposure time (XT) or peen time for the workpiece is determined by increasing the peening cycle to a value equal to or greater than two times the Almen saturation time (2T) to **achieve the desired residual stress** uniformly across the workpiece. (See figure 1).

4.3.9.4 Once the workpiece exposure time (XT) or peen time is determined, Almen strips are processed using this same exposure time (XT) which will determine the Almen arc height for process control purposes. This **Process Arc Height** and exposure time (XT) must be documented on the Shot Peen Process Sheet and in the control plan for the specific part numbers being peened. A control range must be developed and specified for the process arc height.

Note: For this process, arc height is not considered "intensity" (by definition). Process arc height will be somewhat greater than the intensity value specified for that part due to longer exposure to the shot.

4.3.10 AREA OF SHOT PEENING

4.3.10.1 The shot peen process shall be set up such that an optimum impingement angle is obtained in order to obtain the specified compressive stress level. The shot is to be precisely directed at the drive side tooth root fillets mid-way between the heel and toe.

4.3.11 COVERAGE

Part coverage shall be determined in accordance with SAE J2277.

4.3.11.1 Shot peening coverage is to be a minimum 100% of the surface area of the component to be peened. For gears, the specific surface to be peened is the drive side tooth root from heel to toe.

4.3.11.2 Complete coverage (100%) is defined as a uniform and complete dimpling of the original surface. Visual examination, using 10X magnification or other suitable methods, of the peened surface shall exhibit completely overlapping dimples in the tooth root fillet area extending up the tooth at a minimum to the pitchline.

4.3.12 RESIDUAL STRESS PROFILE in SHOT PEENED LOCATION

4.3.12.1 Residual stress measurements shall be performed on untested parts.

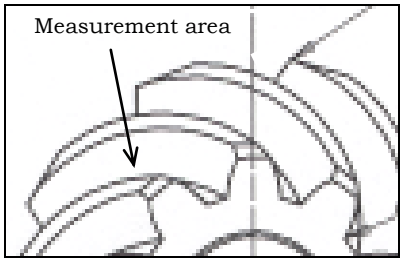
4.3.12.2 The residual stress values shall meet the requirements of the method stated on the component print and listed in Table 1.

4.3.12.3 Measurements shall be made using x-ray diffraction (XRD) techniques at the surface and at 0.025mm (.001"), 0.050mm (.002"), 0.076mm (.003"), and 0.127mm (.005") below the surface per **AAM Procedure ENG-2-434.**

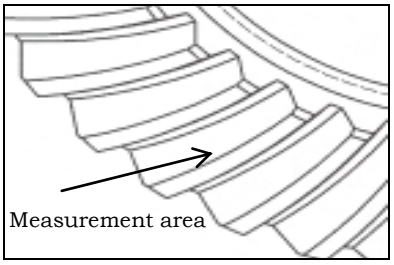
4.3.12.4 Measurements shall be taken on the drive side of the gear tooth near the tooth root fillets ½ way between the heel and toe as shown in Figure 2. NOTE: The drive side of the tooth may change from convex or concave depending on the design and application.

4.3.12.5 If the residual stress measurement will be performed by a source other than the AAM Corporate Materials Laboratory (CML) there must be correlation established between the proposed source and the XRD used at the CML. Correlation and any required correction will be determined by comparison to known standards. Contact the AAM CML for approval process. Approved Non-CML XRD Sources are listed below.

Approved XRD Source / Location	Correction Factor
AAM Corp. Materials Lab / Rochester Hills, MI	----



Drive side, pinion.



Drive side, ring gear.

Figure 2. Area of residual stress measurement.

4.4 PROCESS CONTROL

4.4.1 A process quality control plan for maintaining the approved process set-up is required. This quality control plan should include the process intensity, process arc height, system pressure, shot media flow rate, work piece rotation, component peen cycle time, nozzle distance and alignment, and workpiece coverage.

4.4.2 Process parameters will be documented and agreed upon by both the shot peening source and AAM.

4.4.3 Statistical Process Control (SPC) techniques shall be used to determine process stability.

4.4.4 Residual stress analysis shall be performed on a regular basis in order to ensure that the process intent is maintained. The AAM Corp. Materials Engineering or the responsible metallurgical department shall determine the frequency of analysis.

4.4.5 The Almen strip gage is to be calibrated a minimum of 1x/year and reset (zero adjustment) prior to each Almen strip measurement.

4.5 INSPECTION and REJECTION

4.5.1 Parts shall be dry and oil free after shot peening.

4.5.2 Non-conforming parts or parts processed with unauthorized modifications will be subject to rejection.

4.5.3 Re-shot peening parts is permissible only when there is a process fault during the original shot peen operation that results in an incomplete peen or under peen condition.

4.5.4 Gear Processing – Post Shot Peen
Once a gear surface has been peened, no manufacturing processing can be performed on that surface that will reduce the compressive stresses from peening. Post processing that involves elevated temperatures must be approved by AAM Corp. Materials Engineering.

4.6 SOURCE APPROVAL

4.6.1 The following facilities are approved for shot peening gears for AAM:

Source	Location
Advanced Material Processing Corp.(Metal Improvement)	Wayne , MI
AAM	Changshu, China
AAM	Detroit, MI
AAM	Guanajuato, Mexico
AAM	Araucaria, Brazil
AAM	Three Rivers, MI
Engineered Abrasives	Worth, IL

4.6.2 Any material or process change requires prior approval from AAM Product Engineering as well as the receiving plant metallurgical department.

4.6.3 Source approval requires conformance to the requirements of this specification as well as AAM Product Engineering approval. Representative parts may require Product Engineering durability testing.

5.0 ACCOUNTABILITY

5.1 The functional manager of Materials Engineering is responsible for the implementation, approval and maintenance of this procedure.

6.0 REVISION LEVEL

Revision Level	Date	Revision
0	16 Dec 1999	Original release.
1	23 Apr 2001	Revised Method B and added Method C to address differences in AAM and AMP processing. Added GGA as approved source.
C	**1 Apr 2009**	**Updated spec to allow flexibility for components other than rear drive hypoid gears. Method C deleted and replaced by method B, CW-32.**

Appendix A: MS-10001

AMERICAN AXLE & MANUFACTURING – Site:				
METALLURGICAL PROCESS SET-UP & CONTROL SHEET – Shot Peen				
PART NAME:		PART NUMBER(S):		
Department	Operation Number			
		Issue Date:	Rev. Date:	Form No.:

PART BLUEPRINT SPECIFICATION

Shot Peen Requirement	Shot peen after heat treatment per AAM MS-10001

DEVELOPED PROCESS PARAMETERS

Equipment Name & Number:	
Shot Type / Size	
Peen Time (per station)	
Peen Air Pressure	
Shot Flow	
Spindle RPM	
Nozzle Distance / Alignment	
Nozzle Size	
Shot Coverage	100% minimum
INTENSITY REQUIREMENT	
Process Arc Height (actual)	
Process Arc Height Control Range	
Residual Stress (.002-.003")	

SATURATION CURVE

PEEN TIME (sec)	ALMEN STRIP ARC HEIGHT (mm)	
5		INTENSITY
10		
15		
20		
25		
30		
40		

QUALITY CONTROL

Parameter	Specification	Frequency / Responsibility
Process Arc Height (Almen Strip)		Every Shift and after maintenance. / Operator
Part Shot Coverage	100% min.	Every Shift and after maintenance. / Operator
Shot Hardness	Per MS-10001-1	Every Month / Metallurgy Lab
Shot Seive Analysis		Every Month / Metallurgy Lab
Nozzle location		Every Month / Metallurgy Lab
Residual Stress Analysis		Every Month / Metallurgy Lab

REMARKS

- This document is to be created for each part number being shot peened and a copy must be available at the shot peen machine.
- This document is created and controlled by AAM Corp. Metallurgy and the Mfg. Plant Metallurgy Dept.

ORIGINATED BY:		APPROVED BY:	
			Manager of Metallurgy

Form: Appendix A MS-10001