SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2449

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Grinding of HVOF Sprayed Tungsten Carbide Coatings Applied to High Strength Steels

1. SCOPE:

1.1 Purpose:

This specification covers engineering requirements for the grinding of tungsten carbide High Velocity Oxygen/Fuel (HVOF) thermal spray coatings applied to high strength steels (220 ksi and above).

1.2 Application:

This process has been used typically to grind tungsten carbide HVOF coatings applied in accordance with AMS 2447 or AMS 2448 to high strength steels for applications requiring wear, heat, and corrosion resistance or dimensional restoration, such as aircraft landing gear components. However, usage is not limited to such applications. This process specification does not cover superfinishing of HVOF applied coatings.

1.3 Safety - Hazardous Materials:

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS:

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

TO PLACE A DOCUMENT ORDER:
Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS2449

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

AMS 2447	Coating, Thermal Spray High Velocity Oxygen/Fuel Process
AMS 2448	Coating, Thermal Spray High Velocity Oxygen/Fuel Process

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, PO Box C700, West Conshocken, PA 19428-2959 or www.astm.org.

ASTM E 1417	Fluorescent Penetrant Inspection Methods

2.3 ANSI Publications:

Available from ANSI, 25 West 43rd Street, New York, NY 10036 or www.ansi.org.

ANSI B7.1	Safety Requirements for the Use, Care and Protection of Abrasive Wheels
ANSI B74.13	Markings for Identifying Grinding Wheels and Other Bonded Abrasives

3. TECHNICAL REQUIREMENTS:

3.1 Parts to be ground shall have been coated with tungsten carbide coating in accordance with AMS 2447 or AMS 2448.

3.2 Specific surface finish requirements shall be specified by the cognizant engineering authority. Unless otherwise specified, the surface finish shall be 8 R_a maximum.

Note: Superfinishing of surfaces is generally indicated by measured surface finishes less than 8 Ra. Grit sizes used in the ranges above are not capable of producing super finished surfaces. Superfinished surfaces typically have higher bearing area ratios than as-ground surfaces. Ra = Arithmetic Average (Micro-inch) surface finish.

3.3 Equipment:

3.3.1 Grinding Equipment: Grinding equipment shall be capable of maintaining grinding wheel speed, workpiece speed, traverse or cross feed speed, and (down feed) infeed in increments necessary to avoid surface degradation of the part. Provisions shall be made to supply a constant application of cutting fluid (coolant) to the working surface of the wheel at the grinding zone interface.

3.4 Materials:

3.4.1 Grinding Wheels: Diamond abrasive resin bonded grinding wheels shall be used. Grinding wheels shall be labeled with the complete grinding wheel specification including abrasive type, grit size, grade, bond type and maximum operating speed in accordance with ANSI B74.13. Care and protection of grinding wheels, including proper storage, handling and mounting, shall be in accordance with ANSI B7.1.

3.4.1.1 Each of the following parameters shall be met when selecting a grinding wheel.

Abrasive - Diamond.
Bond - Resin
Grit or Grain Size - 100 to 400 grit
Hardness or Grade of resin bonded portion of wheel - H, L, M, N, P, or R
Concentration - 75 to 125

3.4.2 Cutting Fluids (Coolants): A suitable cutting fluid shall be used which does not have an adverse effect on the part being ground. Recirculating cutting fluids shall be continuously filtered to minimize recycling grinding residue and swarf. A coolant nozzle sufficiently wide to flood the entire width of the grinding wheel shall be used. For proper application of the cutting fluid, the cutting fluid nozzle should be designed to deliver cutting fluid at a speed equal to or slightly faster than the peripheral grinding wheel speed. (See Appendix A).

3.5 Cleaning:

Protective coatings and other foreign materials shall be removed from parts prior to grinding to preclude contamination of coolant and wheels. Coolants and grinding residuals that have a deleterious effect on the part shall be removed after grinding. Cleaning materials shall not corrode or otherwise degrade the surfaces of the part.

3.6 Grinding Process Control:

The grinding process shall be performed in accordance with 3.7 to result in metallurgically sound parts. All speeds, feeds, and stock removal parameters are actual and not necessarily machine or indicator readings. Prior to grinding, clean all surfaces to be ground as stated in 3.5.

3.6.1 Balance the grinding wheel assembly at the time the wheel is mounted. If the grinding wheel remains on the machine arbor it will not need to be balanced again. If the grinding wheel is removed from the machine/arbor it should be re-balanced at the next mounting. True the wheel face so that it is geometrically correct for the application and runs concentric with the centerline of the arbor assembly (see Appendix B). Dress the grinding wheel frequently during use to keep the wheel open with sharp grit exposed to freely cut the work material.

3.6.2 Flood the entire width of the grinding wheel at the wheel-work interface with a filtered continuous flow of cutting fluid.

3.7 Grinding Parameters:

3.7.1 Use a peripheral grinding wheel speed of 4800 to 6500 surface feet per minute (SFPM).

3.7.2 Use cross feeds/traverse rate and infeeds as follows:

3.7.2.1 Cylindrical and Internal Grinding:

3.7.2.1.1 Roughing Infeeds: The roughing infeed (on the diameter) shall not exceed a maximum of 0.002 inch for 100 or 120 grit, 0.0015 inch for 150 grit, 0.001 inch for 180 grit, 0.0008 inch for 220 grit, 0.0006 inch for 320 grit, or 0.0004 inch for 400 grit for each pass. Incremental infeed shall be done at each end of the traverse or crossfeed to maintain wheel face flatness. Use a roughing cross feed or traverse rate of 1/4 to 1/8 wheel width per workpiece revolution.

3.7.2.1.2 Finishing Infeeds: A minimum of 0.002 inch stock removal per side (0.004 inch on diameter) is required for finish grinding. The finishing infeeds (on the diameter) shall not exceed a maximum of 0.0005 inch for 100 or 120 grit, 0.0004 inch for 150 grit, 0.0003 inch for 180 grit, 0.0002 inch for 220 grit, or 0.0001 inch for 320 or 400 grit for each pass. Incremental infeed shall be done at each end of the traverse or crossfeed to maintain wheel face flatness. Use a finishing cross feed or traverse rate of 1/8 to 1/12 wheel width per workpiece revolution.

3.7.2.2 Surface Grinding:

3.7.2.2.1 Roughing Infeeds: The roughing infeed (depth of cut) shall not exceed a maximum of 0.001 inch for 100 or 120 grit, 0.0008 inch for 150 grit, 0.0005 inch for 180 grit, 0.0004 inch for 220 grit, 0.0003 inch for 320 grit, or 0.0002 inch for 400 grit for each pass. The cross feeds shall not exceed 0.080 inch per pass. Table speeds shall be 50 to 75 feet per minute.

3.7.2.2.2 Finishing Infeeds: A minimum of 0.002 inch stock removal is required for finish grinding. The finishing infeeds (depth of cut) shall not exceed a maximum of 0.0005 inch for 100 or 120 grit, 0.0004 inch for 150 grit, 0.0003 inch for 180 grit, 0.0002 inch for 220 grit, or 0.0001 inch for 320 or 400 grit. The cross feeds shall not exceed 0.080 inch per pass. Table speeds shall be 50 to 75 feet per minute.

3.7.3 When grinding OD surfaces, the work should have a speed of 60 to 100 surface feet per minute. When grinding ID surfaces, the work should have a speed of 75 to 200 surface feet per minute.

3.7.4 Table 1 contains general guidelines for surface finish generation for the grit sizes indicated above. Traverse grinding with spark-out or dead passes (i.e. passes with no infeed) may produce finer finishes than shown here.

Table 1. Surface Finish vs. Grit Size

Grit Size	Roughing Mode	Finishing Mode
100-120	32-36 Ra	18-32 Ra
150	22-26 Ra	12-20 Ra
180	18-22 Ra	8-14 Ra
220	12-16 Ra	6-12 Ra
320-400	8-11 Ra	4-10 Ra

3.8 Inspection Requirements:

All ground surfaces shall be visually inspected without magnification for evidence of overheating (discoloration), cracks, flaking or peeling. Ground surfaces shall be checked for surface finish.

3.9 Fluorescent Penetrant Inspection:

All ground surfaces shall be inspected by fluorescent penetrant inspection in accordance with ASTM E 1417 or approved alternate procedure.

4. QUALITY ASSURANCE:

4.1 Monitoring of the process and examination of the finished items shall be in compliance with local quality assurance provisions which ensure that the requirements of this specification are met.

4.2 The coated surface shall be free from heat checks, pull-outs, cracks, and separation from the base metal. Penetrant inspection, in accordance with ASTM E 1417, Type I, Level 2, or higher, shall be used to check for cracking caused by, or revealed by, grinding; and separation of the thermal spray coating from the base metal along the periphery of the coating. Examine for heat checks and pull-outs visually using up to 40X magnification. Etching prior to penetrant inspection is not required.

4.3 The process description and control factors shall be documented on a Grinding Process Control sheet in accordance with Figure 1 prior to commencement of production grinding.

4.4 The processor of parts ground in accordance with this specification shall make no significant change to the process description, or to the materials, processes, or controls referenced in the process description (see Figure 1) unless the change is approved by the cognizant engineering organization. A significant change is one which deviates more than plus or minus ten percent of the approved baseline.

4.5 If the results of any inspection fail to meet the specified requirements, the process is nonconforming. No additional parts shall be processed until the process is corrected and new specimens are coated and ground. Results of all tests shall be recorded and when requested, reported. Purchaser shall be notified of all parts ground since the last successful inspection.

5. PREPARATION FOR DELIVERY:

5.1 Finish ground parts shall be handled and preserved and packaged to ensure that the required physical characteristics and properties of the ground coating are preserved.

5.2 Packages of parts shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the parts to ensure carrier acceptance and safe delivery.

6. ACKNOWLEDGMENT:

Processor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS:

Parts, which have non-compliant surface finish coating that does not conform to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES:

8.1 Dimensions are in inches.

8.2 Terms used in AMS are clarified in ARP1917 and as follows:

8.2.1 Balance (Dynamic): Dynamic balance is the balancing of the complete rotating assembly; grinding wheel, mounting arbor, and the machine spindle. Depending on the balancing machine, the balance condition is measured and corrected at wheel speed.

8.2.2 Balance (Static): Static balance is the balance of the grinding wheel mounted on an arbor, typically balanced on a pair of knife-edges.

8.2.3 Bearing Ratio: The ratio of material to air in a horizontal slice through the surface profile expressed as a percentage. The zero percent or reference line for the bearing ratio is located at the top of the highest peak within the evaluated profile. The bearing ratio is measured at different depths through the profile and varies with slice depth.

8.2.4 Concentration: The amount of superabrasive material contained in a unit volume of the grinding wheel. The measurement is based on the number of carats of superabrasive material per unit volume. Typical concentration numbers are in the range of 30 to 175. A concentration of 100 does not mean 100 percent and therefore is not the maximum concentration. A concentration of 100 means that there are 4.4 carats of abrasive per cm^3 (or 72 carats/cu. in. or 25 volume percent). The abrasive concentration of the selected grinding wheel, for grinding HVOF applied tungsten carbide coatings, is based upon the area of contact between the wheel and workpiece. A large contact area may dictate a low concentration and a small area of contact may dictate a higher concentration so the wheel can hold form and resist premature wear. Since OD grinding generally has smaller contact areas than ID grinding, the concentration of the abrasive in the grinding wheel should generally be higher for OD grinding and lower for most ID applications.

8.2.5 Coolant: Coolant is the misnomer for cutting fluid. The cutting fluid not only cools; it also lubricates and washes away chips and debris. The better term is cutting fluid.

8.2.6 Cutting Fluid: Cutting fluid is the fluid used to cool, lubricate, and wash clean a machining process. Cutting fluids may be oils, water-based synthetic, or soluble oils and gases.

8.2.7 Dressing: Dressing/sharpening is the process of conditioning the wheel surface so as to achieve a certain grinding behavior. Dressing a resin-bonded grinding wheel entails removing some of the bond to expose the grain. This is accomplished by using an aluminum oxide or silicon carbide stick to "stick" the wheel. "Sticking" is best performed wet.

8.2.8 Grade: The grade of a grinding wheel usually refers to the hardness of the bond system. This is determined by the size, type, and amount of filler materials incorporated in the plastic binder material. For the standard code for grinding wheel grades refer to ANSI B74.13.

8.2.9 Grain Size: The grain size refers to a number which corresponds to the U.S. Standard wire mesh size screen used for sizing the abrasive grain. This size is also defined by average particle diameter in accordance with ASTM B 214.

8.2.10 Grit Size: Another term for abrasive grain size.

8.2.11 Infeed: The infeed or down-feed is the feed motion of the grinding wheel into the workpiece.

8.2.12 Spark-out: This is the grinding of a workpiece at the end of the stock removal cycle without engaging any further downfeed (infeed). The grinding forces are allowed to subside with time, ensuring a precision surface.

8.2.13 Superabrasive: Diamond or Cubic Boron Nitride (CBN) abrasives.

8.2.14 Superfinishing: A process used to produce high quality surface finishes with an average surface roughness equal to or less than 8 µinches R_a, and a higher bearing area ratio, T_p, than ground surfaces.

8.2.15 Surface Finish: Surface finish is the smoothness of the machining marks on the surface of a workpiece. Surface finish is measured by moving a precision stylus across the surface and measuring the amplitude of the fluctuations of the stylus.

8.2.16 Swarf: Swarf is the mass of chips and debris remaining after a grinding process.

8.2.17 Thermal Damage: Thermal damage is metallurgical damage which occurs to a material when it is subjected to temperatures which will affect its metallurgical structure.

8.2.18 Truing: Truing a grinding wheel is the procedure of making the grinding wheel geometrically correct for the application and to ensure it is rotating concentric to the center line of the spindle.

8.2.19 Brake Truing Device: A brake controlled truing device is a grinding wheel mounted on an arbor and bearing housing, which has a friction brake to limit its speed. Such a brake-controlled truing device can be used to true resin-bonded superabrasive grinding wheels. Note: Brake controlled truing devices are useful for truing grinding wheels up to 12 inch diameter.

8.2.20 Wheel Speed: Wheel speed is the peripheral speed of the grinding wheel. It is calculated by the following formula: Wheel Speed (Surface Feet per Minute) = Wheel Diameter (in inches) x RPM x .262. For metric equivalent, Meters per Second (m/sec. x 196.85 = SFPM)

8.3 Purchase documents should specify not less than the following:

AMS 2449
Type of coating to be ground
Coating thickness required after grinding
Coating acceptance criteria if not specified herein
Quantity of parts to be ground.

8.4 Key Words:

Grinding, HVOF, wear resistant, corrosion resistance, dimensional restoration, superabrasive, concentration, cutting fluid, dress, true

APPLICATION:
PART NAME:_____ MACHINE NAME:_____
PART NUMBER (VENDOR CODE):_____ (_____)

WHEEL CLASSIFICATION:_____
WHEEL MANUFACTURER:_____

WHEEL: DIA_____ RPM_____ SFPM_____ WIDTH_____

WORK PIECE DATA:
DIAMETER_____ RPM_____ SFPM_____ LENGTH OF TRAVERSE_____
AMOUNT OF MATERIAL TO BE REMOVED BY GRINDING_____
BASE MATERIAL_____ UTS OR HARDNESS_____
CUTTING FLUID_____ CONCENTRATION_____

GRINDING PARAMETERS

TRAVERSE GRIND: ROUGHING	TRAVERSE GRIND: FINISHING
_____ Workpiece RPM	_____ Workpiece RPM
_____ Roughing Traverse Rate	_____ Finishing Traverse Rate
_____ Traverse Rate (Inches/Minute)	_____ Traverse Rate (Inches/Minute)
_____ Sec. Traverse Time for Length of Traverse	_____ Sec. Traverse Time per Length of Traverse
_____ Rough Infeed per End	_____ Finish Infeed per End
Rough Until _____ From Finish Size	
_____ Finish Infeed per End	
_____ Sec. Dwell Time Left	_____ Dwell Time Left
_____ Sec. Dwell Time Right	_____ Dwell Time Right
_____ No. of Spark-out Passes	_____ No. of Spark-out Passes
_____ Total Cycle Time	_____ Total Cycle Time

TOTAL DIMENSIONAL TOLERANCE_____ SURFACE FINISH REQUIRED_____ µin R_a
SPECIAL MACHINING INSTRUCTIONS: Check wheel speed before starting.
Verify roughing traverse rate (xxx Seconds/xxx inches length of roughing traverse) prior to grinding.
Verify finishing traverse rate (xxx Seconds/xxx inches length of finishing traverse) prior to grinding.

OPERATOR: _____ CERTIFICATION NO: _____
APPROVAL: _____ DATE: _____

Figure 1 - Grinding Process Control Sheet