



**KSC Engineering Directorate  
Materials Science Division**

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# **Development of HVOF Superfinishing Spec**

## **Development of Grinding Spec for High Strength Steel and Cr Plate**

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- **Development of HVOF Superfinishing Specification**
- **Draft AMEC – 07AC**
- **To be published as AMS Specification**
- **Superfinishing of HVOF Sprayed Tungsten Carbide Coatings Applied to High Strength Steels**
- **Oscillating Stone Method**
- **Tape or Abrasive Film Method**



- **Oscillating Stone Method**
  - Type and grit sizes of abrasives to be used
  - Cutting fluids/coolants
  - Workpiece surface speeds
  - Contact pressure for stones
  - Traverse rates
  - Stone oscillation rates
  - Polishing with diamond paste



- **Tape or Abrasive Film Method**
  - Microfinishing Film
  - Lapping Film
  - Type and grit sizes of abrasives to be used
  - Cutting Fluids/Coolants
  - Workpiece surface speeds
  - Film index rates
  - Contact pressure for film superfinishing
  - Traverse rates
  - Film oscillation frequency



- **Requirements for surface finish parameters after superfinishing**
- **April 24-25, 2006 A-5 Landing Gear Mtg**
- **Sacramento, CA**
- **To discuss inconsistencies in surface finish parameters used to characterize a surface finish**
- **Need for more standardized parameters and terminology to characterize or define appropriate surface finishes**
- **Some examples to illustrate . . .**



- **Four of the major equipment suppliers for surface finish measurements include:**
- **Mahr-Federal**
- **Mitutoyo**
- **Taylor-Hobson**
- **Hommel**
- **Parameters may differ between various equipment manufacturers depending on profilometer used**
- **This is another example of the need for more standardized parameters and terminology**



- **R<sub>p</sub> – Maximum peak height within sampling length**
- **R<sub>max</sub> – Maximum peak-to-valley height within one cut-off length**
- **R<sub>pm</sub> – mean of 5 peak heights within 5 cut-off lengths**
- **R<sub>pk</sub> – Reduced peak height**
- **R<sub>vk</sub> – Reduced valley depth**
- **R<sub>y</sub> – Highest peak to lowest valley within evaluation length**
- **R<sub>t</sub> – Highest peak to lowest valley within evaluation length**
- **R<sub>z</sub> – Highest peak to lowest valley within sampling length**
- **R<sub>z</sub> – Avg of 5 max pk-to-valley heights within 5 cut-off lengths**
- **R<sub>tm</sub> – Mean pk-to-valley height within evaluation length**
- **R<sub>v</sub> – Maximum valley depth within sampling length**
- **R<sub>vm</sub> – Mean valley depth over 5 cut-off lengths**
- **Mr<sub>1</sub>, Mr<sub>2</sub> – bearing ratio at different slice depths**
- **Mr<sub>1</sub> – Peak material ratio**
- **Mr<sub>2</sub> – Valley material ratio**



- **Inconsistencies in surface finish parameters used to characterize a surface finish**
- **Examples demonstrating the need for more standardized parameters and terminology . . .**
- **$R_{mr}$  ,  $R_{tp}$  ,  $M_r$  ,  $T_p$  are all used to describe bearing ratio or material ratio**
- **The parameter  $R_z$  is found in two standards:**
  - ISO 4287
  - DIN 4768
  - They are not the same, therefore the suffix (ISO) or (DIN) must be used to avoid confusion.
- **$R_z$ (ISO) and  $R_z$ (DIN)**



- **$R_z(\text{DIN})$  – average of the five maximum peak to valley heights within each of the five cut-off lengths being evaluated**
- **$R_z(\text{ISO})$  – “ten point height” is the average distance between the 5 highest peaks and the five deepest valleys within the assessment (evaluation) length.**
- **Unlike  $R_z(\text{DIN})$ , the five peaks and valleys used to calculate  $R_z(\text{ISO})$  can be located anywhere along the assessment length. The disadvantage of  $R_z(\text{ISO})$  is that it is possible to have a number of high peaks or valleys located close together. These peaks and valleys are not representative of the entire surface over which the assessment is made and may not indicate the average condition over the assessed profile.**



- **ARP 5935 (published 2007) Use of HVOF Thermal Spray Coatings for Hard Chrome Replacement in Landing Gear Applications**
  - Type 1 are surfaces that require seals/hydraulic fluid/sliding member
  - Examples include Landing Gear Strut and Actuator Piston Barrels
  - To maximize seal life, Superfinishing is required
  - Recommended surface finish parameters include:
    - Ra 4  $\mu$ inch or better
    - Rz 40  $\mu$ inch max (avg. peak-to-valley)
    - Rp 8  $\mu$ inch max (mean line to highest peak)
    - $R_{mr}$  70 to 90% @  $C_0 = 5\%$  and  $C_1 = 0.25R_z$



- **Use of HVOF Thermal Spray Coatings for Hard Chrome Replacement in Other Applications**
- **Hydraulic Actuator Piston Rods**
  - Applications with seals/hydraulic fluid/sliding member
  - Hydraulic Actuator Piston Rods
  - To maximize seal life, Superfinishing is required
  - Recommended surface finish parameters may include:
    - Ra 4  $\mu$ inch or better
    - Rz 40  $\mu$ inch max (avg. peak-to-valley)
    - Rp 8  $\mu$ inch max (mean line to highest peak)
    - $R_{mr}$  70 to 95% @  $C_o = 5\%$  and  $C_1 = 0.25R_z$



- Bearing Ratio or Material Ratio
- $R_{mr}$  70 to 90% @  $C_o = 5\%$  and  $C_1 = 0.25R_z$
- 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 may be measured at different depths (e.g.  $C_1$ ,  $C_2$ ,  $C_3$ ) through the profile and varies with slice depth.
- To avoid dependence of the bearing (or material) ratio on a single peak, a reference line is selected to shift the reference line below the highest profile peak.
- The reference line is specified as a bearing (material) ratio percentage.



- Specifying a five percent reference line indicates that the top five percent of the profile is not included in the bearing ratio calculation.
- A reference line of  $C_{ref} = 5\%$  (also referred to as  $C_o = 5\%$ ) is commonly used for applications covered by this specification.
- A slice depth of  $C_1 = 0.25Rz$  is commonly used as the slice depth at which to measure bearing ratio for applications covered by this specification.
- Other slice depths commonly used include 6, 8, & 10  $\mu$ inch



- **Development of High Strength Steel & Chrome Grinding Specification**
- **Draft AMEC – 08AA**
- **To be published as AMS Specification**
- **Low Stress Grinding of High Strength Steel Parts Heat Treated to 180 KSI or Over, and Low Stress Grinding of Chrome Plating Applied to High Strength Steel Parts Heat Treated to 180 KSI or Over**
- **This Grinding Specification provides an option or an alternate to MIL-STD-866 which is no longer active for new design**



- **Barkhausen Noise or “Rollscan” Inspection**
- **Barkhausen noise detects changes in magnetic domains within the material when subjected to an alternating magnetic field, applied by a probe at the surface.**
- **This technique is very sensitive to localized changes in microstructure and residual stress gradients.**
- **Barkhausen noise inspection procedure is covered in ARP 4462, LGPS 3001 (for Goodrich) and BAC 5653 (for Boeing parts).**



- **The BNI (Barkhausen requirement), for first article inspection may force some facilities to request assistance.**
- **Possibly there should be periodic workshops offered on this subject (BNI) for both demonstration and discussion of experiences and approaches.**
- **For example, at the various conferences or meetings where grinding of high strength steel components or grinding of chrome plating on HSS is of concern**



- **Quenched and tempered, low alloy, high strength (i.e. 180 KSI UTS and above), martensitic steels (e.g. 4130, 4330V, 4340, 9310, 300M, etc...) are more susceptible to grinding burn.**
- **Grinding wheel speed should be limited to 4,000 SFPM**
- **Some precipitation hardened alloys (e.g. Ferrium S53, AerMet 100/310/340, Custom 455/465, MLX-17, and others, including the majority of PH stainless grades PH 13-8Mo, 17-4PH, 15-5PH, etc.) may achieve high integrity ground surfaces using higher wheel speeds (e.g. 6,500 SFPM)**