CENTER FOR POWDER METALLURGY TECHNOLOGY

# Troubleshooting Guide for Welding Powder Metallurgy (PM) Parts

Welding powder metallurgy (PM) components poses unique challenges due to their specific properties and microstructures. This guide outlines common problems and solutions to ensure successful welding of PM parts.

**Welding performance issues**

Symptoms:

- Cracks in the weld zone
- High shrinkage in the weld area
- Poor weld integrity

**Commons causes of welding issues:**

- PM components that have lower densities may lead to excessive cracking of welds due to the high stresses from solidification of the weld and excessive oxidation of the weld joint.
- PM components that have carbon levels greater than 0.5% may be prone to higher risk of weld failures.
- PM components that have copper levels greater than 2% may be prone to higher risk of weld failures.

**Improvement opportunities and solutions:**

Select a PM Material designed for welding.

- Use higher density materials: Sintered densities > 6.90 $g/cm^3$ are better suited for applications requiring welding.
- Avoid materials with greater than 2% copper. When higher strength materials are required, consider alloy steels containing nickel, chromium, manganese, or molybdenum.
- See Appendix for typical PM materials that are utilized in applications requiring welding.

**Select the appropriate welding technology:**

When choosing welding techniques for powder metallurgy (PM) parts, Tungsten Inert Gas (TIG), Capacitor Discharge (CD), Electron Beam (E-beam), Laser Beam, and Pulsed Plasma Arc welding typically demonstrate superior performance as compared to Metal Inert Gas (MIG) and conventional electrode or "stick" arc methods.

- **Capacitor Discharge (CD) Welding:** This method is notable for its speed, and competitive cost, completing welds in approximately 20 milliseconds. CD welding produces strong, reliable bonds, making it suitable for applications in automotive and agricultural equipment, such as transmissions and engines. PM parts joined through CD welding are commonly found in heavy-duty pickup trucks and electric vehicles, particularly in components like power steering pulleys. Additionally, CD welding effectively joins dissimilar materials, including aluminum, bronze, stainless steel, and copper to carbon steel and Inconel.
- **Tungsten Inert Gas (TIG) Welding:** Known for its precision and versatility, TIG welding is ideal for thin materials and offers excellent control over the weld pool.

- **Electron Beam (E-beam) Welding:** This technique utilizes a focused beam of electrons, providing high penetration and minimal thermal distortion, making it ideal for thick sections and complex geometries.
- **Laser Beam Welding:** Leveraging concentrated laser energy, this method offers high speed and precision, suitable for both thin and thick materials, and is widely used in industries requiring clean and strong welds.
- **Pulsed Plasma Arc Welding:** This innovative technique combines the benefits of plasma arc and traditional welding, allowing for precise control of heat input and weld characteristics.
- **Metal Inert Gas (MIG) Welding:** While MIG welding is popular for its speed and ease of use, it generally provides less control compared to other techniques, which may impact the quality of the weld.
- **Conventional Electrode or "Stick" Arc Welding:** This method is versatile but typically results in more heat input and distortion, making it less favorable for delicate PM components.

**Contaminants may effect on Weld Quality**

Symptoms:

- Inconsistent weld appearance & weld failures/cracking

Possible causes:

- Presence of contaminants like lubricants, machining oils, or cleaning solutions.

Possible solutions:

- Thorough cleaning: Ensure surfaces are free from oxides, oils, and other contaminants before welding.
- Inspect for residues: Regularly check for contaminants that may affect weld quality.

**Heat Management Problems**

Symptoms:

- Cracking during or after welding and/or distortion of parts

Possible causes:

- Excessive heat input in a local area or inadequate heat management.

Possible solutions:

- Control heat Input: Use lower heat settings to prevent local microstructure degradation.
- Preheat Parts: In some cases, preheating can help mitigate thermal gradients that cause cracking.

**Filler Material Incompatibility**

Symptoms:

- Cracking at the weld interface and/or weak welds

Possible causes:

- Incompatible filler material properties.

Possible solutions:

- Choose compatible fillers: Select filler materials that match the PM part's composition and mechanical properties.

**Post-Welding Recommendations:**

- Stress relief annealing: Performing stress-relief treatments post-welding can reduce or minimize residual stresses in weld, results in more robust PM welds.
- Additional machining may be needed to achieve desired tolerances and finishes.

**General Recommendations:**

- Use non-destructive testing (NDT): After welding, conduct NDT to assess weld integrity.
- Evaluate mechanical properties: Ensure that the welded parts meet the required specifications through testing.

**Conclusion**

Welding PM parts requires a thorough understanding of the material properties and careful selection of welding techniques. By addressing these common issues with the recommended solutions, reliable welds that maintain the integrity of PM components can be sustainable. Proper planning, knowledge, and experience are key to successful welding in this specialized area.

**Appendix**

**Recommended Ferrous PM Materials when the assembly requires welding:**

Tensile Properties

| Ultimate Strength (Typ.) | Recommended PM Materials | Max. Carbon Level |
|---|---|---|
| 35,000 psi | FN-0200-20 | 0.3% |
| 40,000 psi | FN-0200-25 | 0.3% |
| 50,000 psi | FN-0205-25 | 0.5% |
| 54,000 psi | FD-0105-40 | 0.5% |
| 60,000 psi | FN-0205-30 | 0.5% |
| 70,0000 psi | FN-0205-35 | 0.5% |
| 77,000 psi | FD-0105-45 | 0.5% |
| 80,000 psi | FLN2-4405-55 | 0.5% |
| 103,000 psi | FLN4-4405-85 | 0.5% |
| 117,000 psi | FLDN2-4908-90 | 0.5% |

**Compatible weld filler materials:**

When welding, you should use filler metals that are similar to the chemical composition of the alloy being welded or use a filler metal with a higher alloy content to improve corrosion resistance.

| Welding | Recommended filler metal is |
|---|---|
| PM Ferrous Iron or Steel | Carbon equivalency ferrous metal |
| PM Phosphorus Nickel steel | AWS R 309L |
| PM 304 or 304L stainless steel | 308 or 308L. |
| PM 316 or 316L stainless steel | 316 austenitic |
| PM400 series stainless steels | Equivalent material with Cb (Nb) additions |

As applicable, suggested annealing temperatures and cycles

| | |
|---|---|
| Ferrous PM such as FN, FL, FLN | 400° to 500° F in air for 1 hour |
| PM 304 or 304L stainless steel | 400° to 750° F in a vacuum, reducing or an inert atmosphere |
| PM 316 or 316L stainless steel | 400° to 750° F in a vacuum, reducing or an inert atmosphere |

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