Powder metallurgy (PM) is the process of forming metal components by mixing elemental or metal alloy powders, die pressing at high force levels, and heating at temperatures just below the melting points of the particulate materials. This heating process, called sintering, takes place in a controlled-atmosphere furnace and bonds the particulate materials metallurgically. In recent years, the PM process has been shown to be a superior technique for manufacturing high-quality parts compared to forging or metal casting. Advantages include material utilization, shape complexity, and dimensional control, all yielding lower costs and greater flexibility.

Conventional PM, sometimes referred to as press and sinter, yields parts formed by compacting the powder in a single direction. The die forms the compacted shape, referred to as a green part. This shape is limited to definition in the compacting direction so that the green part can be removed from the die without damage.

Sinter brazing is a common joining process used by powder metal part manufacturers. It allows the formation of more complex parts while maintaining desirable levels of material strength. The technique involves assembling multiple powder metal parts, in the green state prior to sintering, adding a braze compound, and sintering at temperatures above the melting point of the brazing alloy. When processed properly, sinter brazing is cost effective and produces a strong joint. Several examples of brazed powder metal parts are shown in Fig. 1.

Certain defects are common among sinter brazed powder metal parts. These include subcomponent misalignment during initial assembly and incomplete braze material infiltration. Inadequate infiltration is typically caused by using an improper brazing alloy or damaged braze pellets (for example, a slug with 50% of its material broken away). Another likely root cause of poor sinter brazing is missing the braze pellet altogether. Other common process variances that can lead to inadequate braze joints include improper furnace settings and dewpoint. Several examples of these defects are shown in Fig. 2.

To ensure the formation of quality parts, the presence of potential defects must be checked. Crack and chip defects, common to the root PM process, should also be tested. The consequences of shipping defective parts include expensive resorting, often at the customer’s site, or contracting additional inspection to a third-party vendor. Ultimately, expensive end product recall costs could become the responsibility of the failed component manufacturer.

Given that typical PM parts are manufactured in medium to high volumes, performing these inspections in a reliable, automated, objective fashion is critical to maintain cost effectiveness. The Resonant Acoustic Method Of Testing Sinter Brazing Integrity Using Resonant Inspection

The process proved effective in detecting defects commonly found in sinter brazed powder metal parts

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Fig. 1 — Examples of sinter brazed powder metal parts with braze plugs inserted as indicated.

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Nondestructive Testing (RAM NDT) from the Modal Shop, Cincinnati, Ohio, provides a technique for these demanding performance requirements.

Resonant inspection (RI), the general process on which the technique is based, measures the structural response of a part and evaluates it against the statistical variation from a control set of good parts to screen defects. Its volumetric approach tests the whole part, both for external and internal structural flaws or deviations, providing objective and quantitative results. This structural response is a unique and measurable signature, defined by a component’s mechanical resonances. These resonances are a function of part geometry and material properties and are the basis for RI techniques. By measuring the resonances of a part, one determines the structural characteristics of that part in a single test.

The Resonant Acoustic Method technique performs RI by impacting a part and “listening” to its acoustic signature with a microphone. The controlled impact provides broadband input energy to excite the part, and the microphone allows for a noncontact measurement of the structural characteristic signature. The part’s mechanical resonances amplify the broadband input energy at its specific resonant frequencies, indicated by peaks in the resulting frequency spectrum (shown graphically in Fig. 3) measured by the microphone. “Good” parts (structurally sound) have consistent spectral signatures (i.e., the mechanical resonances are the same among part samples) while “bad” parts are different (i.e., exhibit resonant frequency shifts from expected values). Deviations in peak frequencies or amplitudes constitute a structurally significant difference in the part’s composition, providing a quantitative, objective, and repeatable part rejection. In simpler terms, just like a cracked bell sounds different when struck, flawed parts sound different and can be sorted accordingly.

The technique has proven effective for inspecting the structural integrity of sinter braze joints. In one such application, the structural integrity of a brazed powder metal carrier gear assembly was tested using the process, and the results correlated with destructive testing. Criteria templates with several critical resonant frequencies were established from a baseline set of parts. This initial set of parts was inspected with visual examination and microstructural analysis, and included acceptable production process variations in density, lot-to-lot powder, dimensions, and sintering effectiveness.

A tensile test of the braze joint was completed on this set of parts. The separation force was measured for a variety of groups of parts, with induced defects including misalignment, omitted braze pellets, small braze pellets, and poor sinter. The results are given in Table 1. Within each of these groups of parts, certain resonant frequencies shifted that allowed accurate and reliable 100% inspection via RAM NDT. Typically, these frequency shifts were on the order of 6–10% as compared to resonant frequency shifts due to acceptable process variation of less than 1%. As a result, it was concluded that the technique can easily and reliably detect poor sinter braze joints.