CARPENTER ADDITIVE®

CASE STUDY

Maraging Steel: The Effects of Alloy Chemistry on Processability

Why is the Specification of a Metal Powder Important?

For metal powders to deliver built parts with the required properties it is critical to define an appropriate material specification, and to include sufficient tolerances to accommodate manufacturing and testing variance. However, it is also necessary to establish limits which are tight enough to ensure any variations do not have an effect on process and application performance. These effects can be on material processability during part manufacture, or the final mechanical properties of the part itself.

A metal powder can not only move from, but also vary within, specification in terms of its chemistry and physical properties. The concentrations of individual elements can differ between powder batches due to unstable manufacturing routes or changes in raw materials, or when comparing multiple powder suppliers. Deviations in size, shape, flow, density, etc., can be due to processing or environmental conditions.

If chemistry-associated issues arise with a component's mechanical properties, it can be that the specification is too loose to adequately control those elements responsible for the performance of the final part and tightening the limits will resolve the issue. This, however, can make the powder specification difficult to achieve, and still may not deliver the expected results.

Background on CT NiMark® Alloy 300 (Maraging steel) DIN 1.2709

Carpenter Additive's CT NiMark Alloy 300 is a low carbon, age hardenable, martensitic steel with exceptional mechanical properties, specifically a high tensile strength and hardness. It is easily heat treated, achieving superior mechanical properties after age hardening. With proven AM suitability, Carpenter Additive's CT NiMark lends itself to tooling applications such as tool inserts for injection molding and die-casting, as well as functional components.

The Problem

Maraging steel powder had been supplied for several years without problems. Two successive batches of material then resulted in micro-cracking within parts during AM processing (Figure 1). The powder fell within the existing specification, which indicated that aspects of powder were not under adequate control. As maraging steel is predominately used in tooling applications which often require a polished finish, cracks revealed at the surface after finishing are unacceptable. In other applications, the tensile properties are also compromised by the presence of micro-cracks in the bulk material.

FIGURE 1

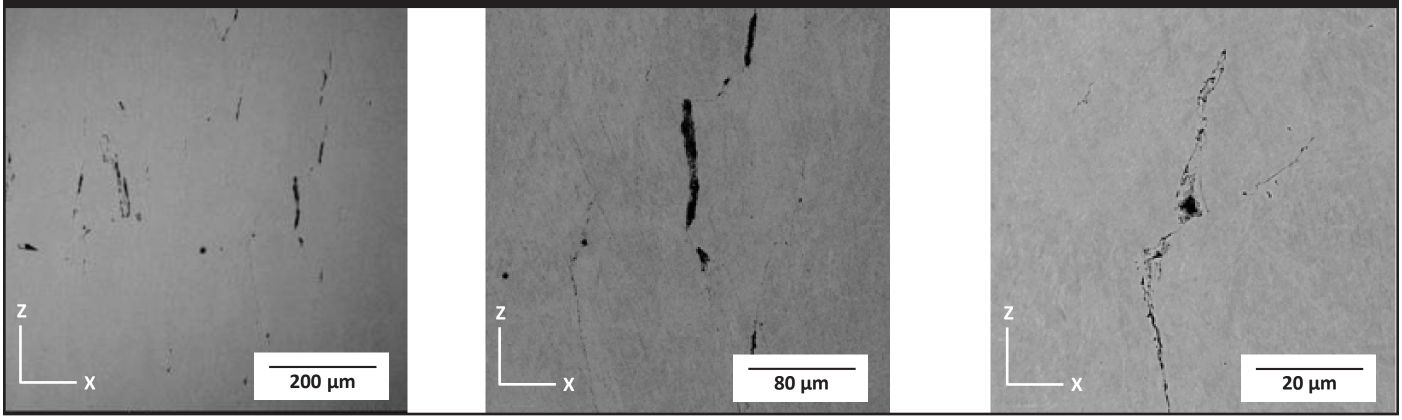

Figure 1. SEM images of micro-cracks observed at grain boundaries of M300 AM parts. Cracks are aligned in the vertical/build-direction

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FIGURE 2

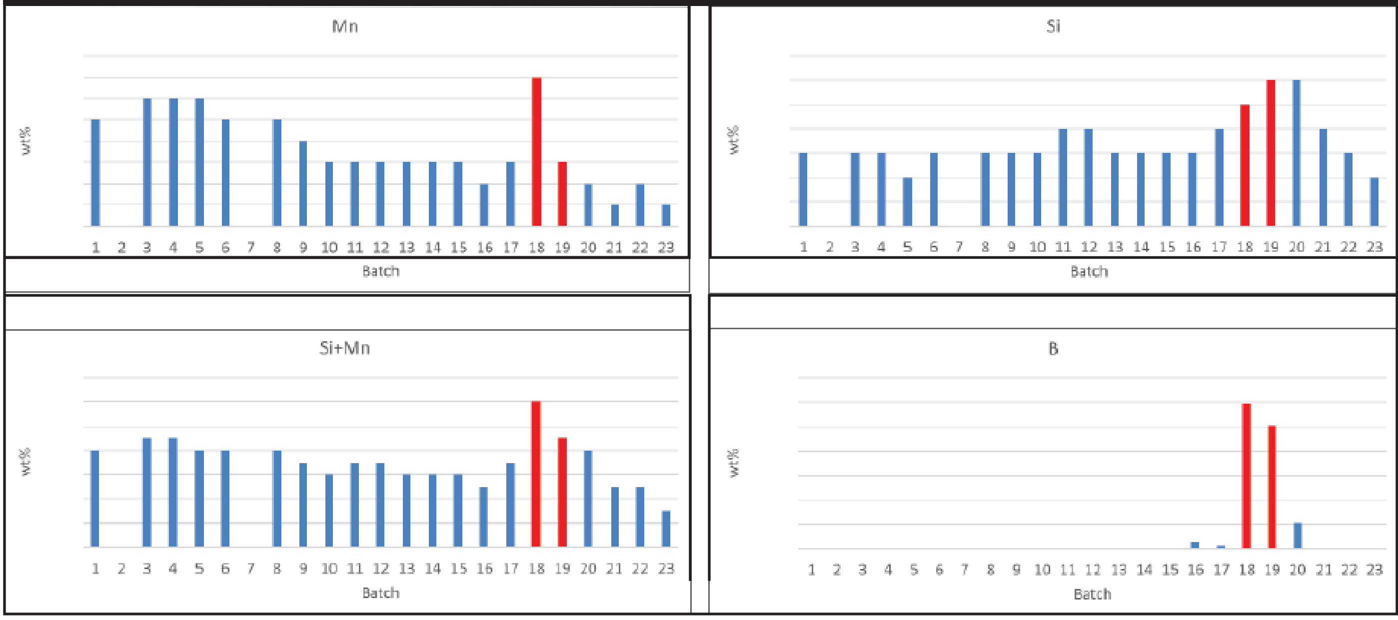

Figure 2. Relative levels of key residual elements across 23 powder batches

The Solution

Carpenter Additive's applications team observed vertical micro-cracking at grain boundaries. With their wealth of experience in metal powders for additive manufacturing, they recognized this as indicative of a material issue rather than a process induced defect, and their investigation focused on the alloy chemistry. The residual elements of Silicon (Si), Manganese (Mn) and Boron (B) showed a variance in the problem batches, but boron proved to be the outlier. Whilst still within the levels of the specification, it was significantly higher than the previous, problem-free batches.

The limits of the three residual elements were tightened sufficiently to ensure the powder delivered the required results. This has resulted in no recurrence of the micro-cracking in subsequent maraging steel powder batches.

The Investigation

Twenty-three historical powder batches were scrutinized for deviations of their alloy composition (Figure 2). Batches 18 and 19 were those which resulted in cracking in AM parts. Mn and Si were first noted as residual elements (elements which may not be deliberately added to the alloy but are present in raw materials, or those which are only controlled to an upper limit) which varied significantly within the specification. There were example batches to suggest that in isolation these elements are not responsible for the defects. Batch 19 (which cracks) has relatively low Mn compared to Batch 18; Batch 20 (which has processed successfully) has high Si. The effect of the combination of Si+Mn does place Batches 18 and 19 as outliers, albeit marginally. Boron was the stand-out element which was significantly different compared to all other successful batches, being 4-5 times higher.

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These results prompted a revision of the alloy chemistry specification to impose tighter limits on these critical elements to ensure control is re-established and future deviations are kept to a minimum. Figure 3 shows the relative levels of Mn, Si, and B received before and after the revision to the alloy specification, the resulting chemistries being achieved through optimal raw material selection prior to atomization.

Ongoing Research

To ensure the powder is not over-engineered, making the specification difficult to achieve, further investigations are being conducted based on alloy simulation and experimentation. This will inform on the cause of the cracking in more detail and will form the basis of further case studies.

FIGURE 3

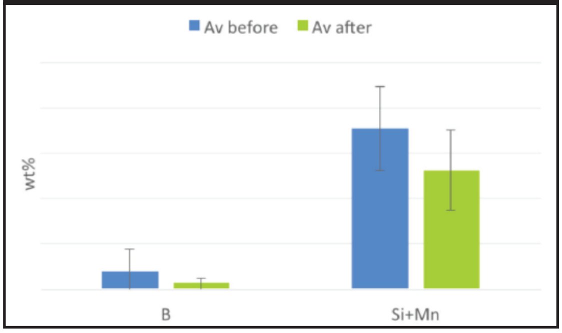

Figure 3. Relative concentration of boron and silicon+manganese in failing M300 batches ('before") and subsequent batches where no cracking was observed ('after')