Metallurgical Analysis of 303 SS Raw Material and Customer Return

**Background:**
In the process of forming a crimp on ground 303 stainless steel, cracking was discovered. In order to determine what caused the cracking, samples of the metal at all stages of processing, from raw material to finished straightening and cutting, were submitted for metallurgical analysis. The objective was to determine what stage in processing caused this abnormality. Additionally, a sample of the “crimp cracked” material was obtained and submitted for comparison purposes and is identified as mount #10.

**Metallurgical Analysis:**
The initial metallurgical examination involved cutting a longitudinal and transverse portion from each of nine samples identified as #1 through #9. Number 1 was cut from the submitted raw material used to process into the required size. All nine bakelite mounts were identified according to their number, ground and polished in accordance with standard ASTM procedures for optical microscopic examination.

**Optical Microscopy:** Both longitudinal and transverse sections were examined in the as-polished condition for inclusion determination, followed by etching each with a solution of mixed acids (HCl, HNO₃, Acetic and Glycerol).

**Results: #1 – Raw Material:** The expected microstructure should exhibit an annealed hot rolled condition. Microstructure was severely overheated during mill processing which caused huge grains to form in the core. The surface grain was severely distorted and did not exhibit a condition normally associated with hot rolling to size. The core and surface microhardness (by Tukin/500g.Knoop to HRC) is identical: ~170 BHN. The finding of a large amount of very fine dispersed inclusions led to an assumption that the material may be 303Se rather than 303SS.

**Results: #2 through #9:** Annealing has not removed the work hardening introduced during the minor surface drawing operation. The internal microstructure has not changed from that observed in the original raw material. This mottled microstructure is due to deficient mill processing and will not revert back to a homogenous grain structure.

**Results: #10**  
Macrostructure:
A thin line crack is easily visible spiraling along the length of the wire. Initially, the crack was thought to have originated at and by the vendor’s two opposing crimp operation. However, this is not the case. It is impossible for a crack to propagate in a spiral manner along the full length of the wire.

**Scanning Electron Microscopy & X-Ray Energy Dispersive Element Analysis (EDS) Data:**
The mounted sections in #10 were examined using a scanning electron microscope equipped with an EDS quantitative element analysis instrumentation. The longitudinal section crack with the large inclusion was analyzed. EDS determined the fine distribution of inclusions observed throughout the microstructure was “Manganese Sulfide”. The large inclusion was also identified as manganese sulfide, along with oxides.

**Conclusions:**
In the opinion of this metallurgist, the cracking was caused by trapped manganese sulfide inclusions introduced by the Mill when the 303 stainless steel was produced. The quality of the material supplied by the Mill was at best, defective and in an unacceptable condition.
Figure 1. A longitudinal section of 303SS representing all material submitted in various stages of manufacturing.

Figure 2. This is a typical area in the longitudinal cross-section showing manganese sulfide inclusions at high magnification.
Figure 3. The mounted sections of 303SS represents material in-stock. The microstructure contains areas of very large grain bordered by very fine grain and a general lack of homogenization of grain size.

Figure 4. The intersection of an fine grain and large grain. The fine lines in the grain structure indicate the metal is slightly work hardened or not full annealed. This is a transverse cross-section.
Figure 5. Rod returned by customer. It contains a spiral crack which extends along the full length, and is indicated in this photo by white arrows near the crimp area.

Figure 6. This magnified view of the bakelite mounted sections from the customer return. The white arrows point to what appears to be cracks. The silver gray material touching these sections is graphite paste required for conductivity in the scanning electron microscope.
Figure 7. This is the transverse view of the spiral defect in the customer returned rod. The shape and trapped inclusions indicate it is likely the result of a fold or Mill processing defect and not a quench crack.

Figure 8. This is the longitudinal view of the spiral defect and trapped inclusions. These inclusions were subjected to SEM / EDS analysis.
Figure 9. The longitudinal defect with a massive inclusion was analyzed using the SEM / EDS x-ray element analyzer. The analysis indicates the inclusion is primarily manganese sulfide with some additional pockets of aluminum and silicon.
Figure 10. The longitudinal defect with a massive inclusion was analyzed using the SEM / EDS x-ray element analyzer. A “General Inclusion Spectra” was taken primarily of the included area; indicating MnS as the primary compound. EDS analysis of other areas found elements as indicated.
Figure 11. The transverse section defect, with a massive inclusion circled, was analyzed using the SEM / EDS x-ray element analyzer. The spectra obtained also found the composition of the inclusion consistent with that of MnS.