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Quantitative Metallography And Microanalytical Analysis Of Particles In Iron Rivets Recovered From The Wreck Of The RMS Titanic

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Since the discovery of the wreck in 1985, various forensic examinations of materials recovered from the wreck of the RMS Titanic have been performed to try to determine if the quality of materials used to build the ship had any influence on how the ship was damaged by the iceberg. The focus of the present study is on the quality of the iron feedstock that went into the ship's rivets[1].

Examination of the wreck using sub-surface sonar, as well as survivor testimony, indicates that the iceberg did not cut the hull plates but rather popped riveted seams. Further testimony from passengers indicates that the impact was both discontinuous and of low severity, bringing into question how these rivets had failed so easily, a riveted seam being designed to be stronger than the plates of which it is composed.

48 rivets and rivet fragments were recovered from the wreck site between 1996 and 1998, many individually but some still part of riveted sections that were recovered whole. Metallographic examination seemed to show that all recovered rivets were wrought iron (nearly pure iron with entrained slag filaments for strength), even though some were taken from regions that should have been steel. Microanalytical analysis of the particles using EDS in the SEM as well as EELS in the TEM (fig.1) showed that what appeared to be iron silicate slag particles in wrought iron were in fact MnS particles, and that the "steel" rivets used had so little carbon content that it contained no pearlite. The true wrought iron samples showed small particles of Fe-silicates, with occasional larger particles that contained dendrites of iron oxide. Quantitative metallographic analysis of the slag particle distributions revealed that the average slag content of Titanic rivets was 9%, more than three times that expected for rivet-quality wrought iron. Further, the morphology of the slag (fig.2) was typically in the form of large (100 to 1000+ micron) particles. Both of these factors indicated poor manufacturing methods, as wrought iron in Edwardian England was an apprentice-learned trade, with hand-made gathers of wrought iron being produced 500 lbs. at at time.

Large slag particles compromise the strength of the iron when used as a rivet, as upsetting the shaft into a second head during installation re-orients the large particles from along the shaft to a transverse orientation within the head and at the head-shaft interface, weakening this interface. A thorough analysis of construction records of Harland and Wolff revealed that, under immense production pressures, the company purchased sub-standard wrought iron rivets from many suppliers other than those with whom they normally did business, in agreement with our metallographic observations.

References

[1] "What Really Sank The Titanic", J. Hooper-McCarty and T. Foecke, Citadel Press, ISBN 0806528548 (2008)
[2] J.J. Hooper-McCarty, PhD Thesis, The Johns Hopkins University (2003)
[3] T. Foecke, "Metallurgy of the RMS Titanic", NISTIR 6118 (1997)

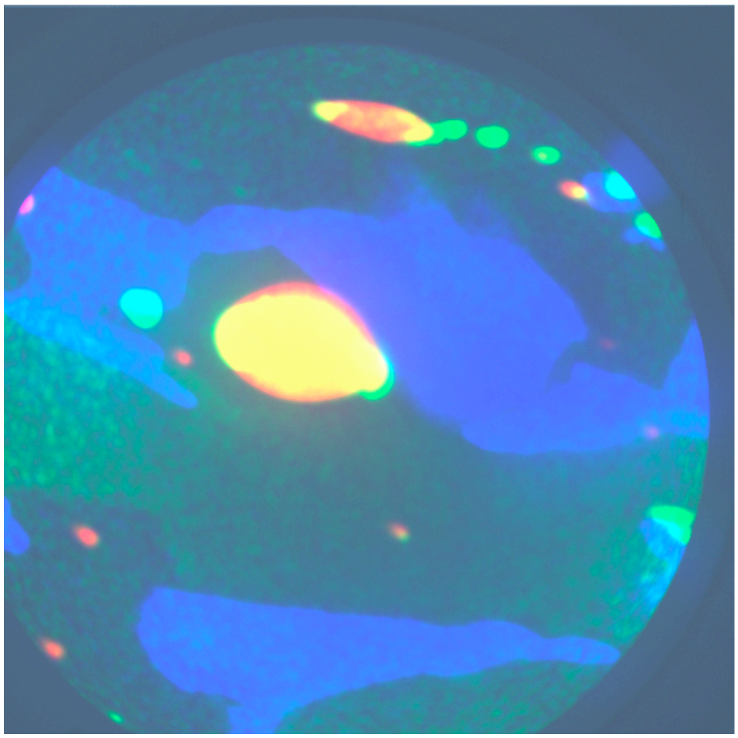

Figure 1: Composite SIMS image showing sulfur (yellow), oxygen (green) and carbon (blue) distribution in iron.

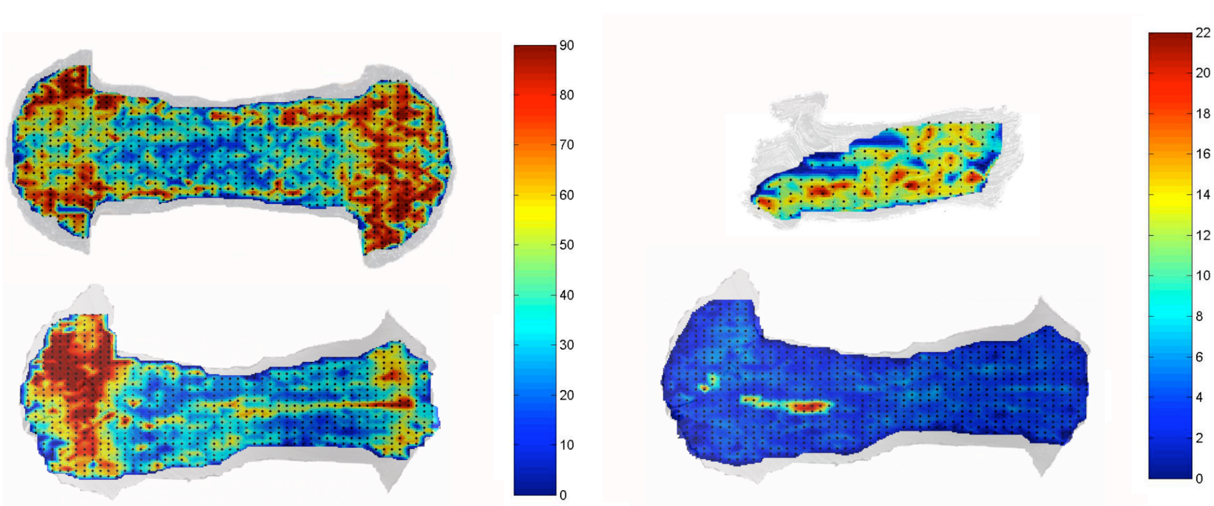

Figure 2: Montage of data from thousands of micrographs, showing particle orientation with respect to tensile axis of rivet (left) and area fraction of particles (right).