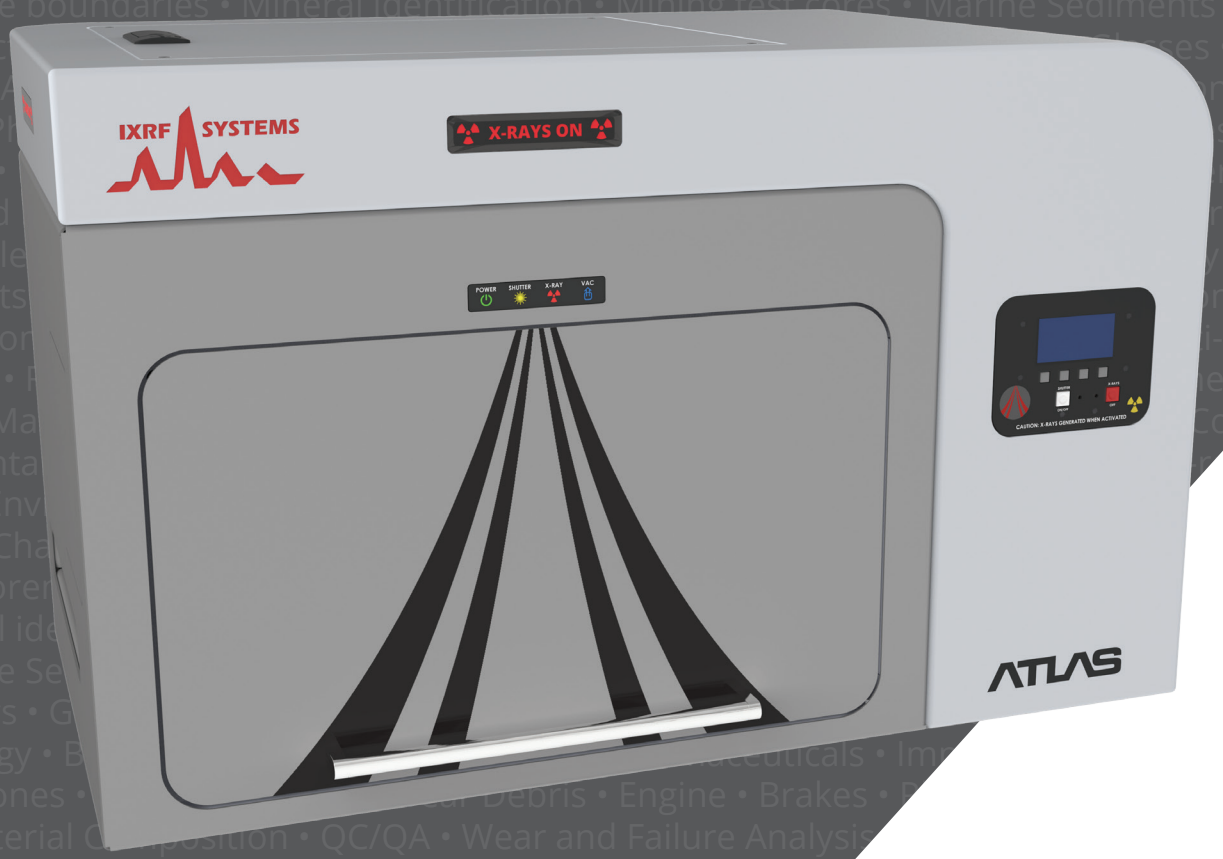


CENTERLINE SEGREGATION IN CONTINUOUS CASTING

IXRF SYSTEMS

Quantitative Measurement of Macrosegregation in Continuously Cast High Strength Steels with Advanced Scanning MicroXRF Spectrometer

Advanced continuously cast high strength low alloy steels are often subject to elemental segregation along the billet or slab centerline during casting and cooling. Monitoring macrosegregation is critical before billet or slab rolling and forming, for if elemental segregation is excessive it can lead to structural weakness, including cracking and breaking of rolled and formed products. Hence, by catching macrosegregation before rolling and forming can save substantially in production costs and material handling and product remelting and casting.

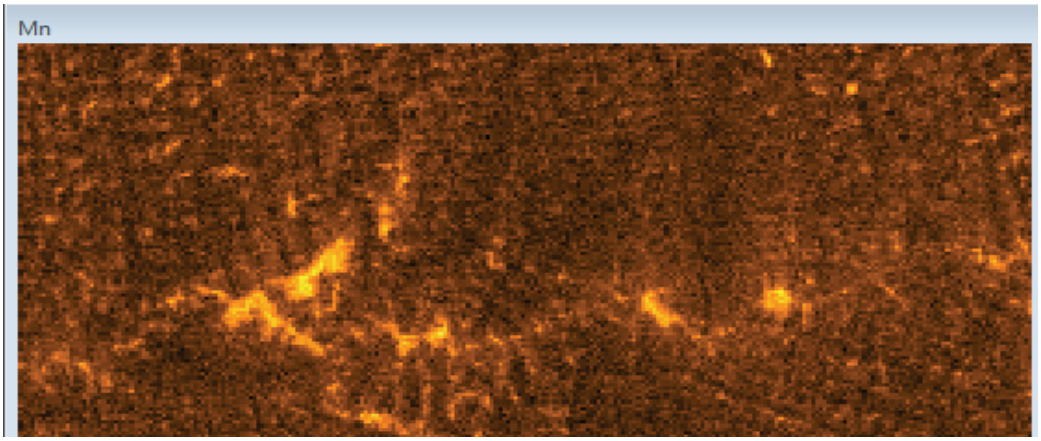
Traditional industry monitoring has been done by etching and optical imaging. This is time consuming and not compositionally quantitative. Results are subjective and difficult to compare if methods and sample preparation are not identical between plants and different steel manufacturers. Etching is subjective and cannot provide quantitative compositional data for meaningful statistical analysis, but can provide information about structural homogeneity.

Now, by employing new advanced scanning micro x-ray energy dispersive spectroscopy technology, it is possible to rapidly scan centerline areas and quantitatively monitor elemental inhomogeneity. Sample preparation is simple, only a clean milled surface is required and pixel concentrations less than one-tenth of a weight percent can be measured and mapped. Pixel size can be varied, as the focused x-ray source can produce beam diameters from 5 to over 100 microns, ideal for rapidly mapping macrosegregation from tens to hundreds of microns. With the x-ray source normal to the sample surface, the exciting area is round and multiple detectors, up to four, can be used to measure higher count rates. Map data files can contain as many as 5 GBs or more.

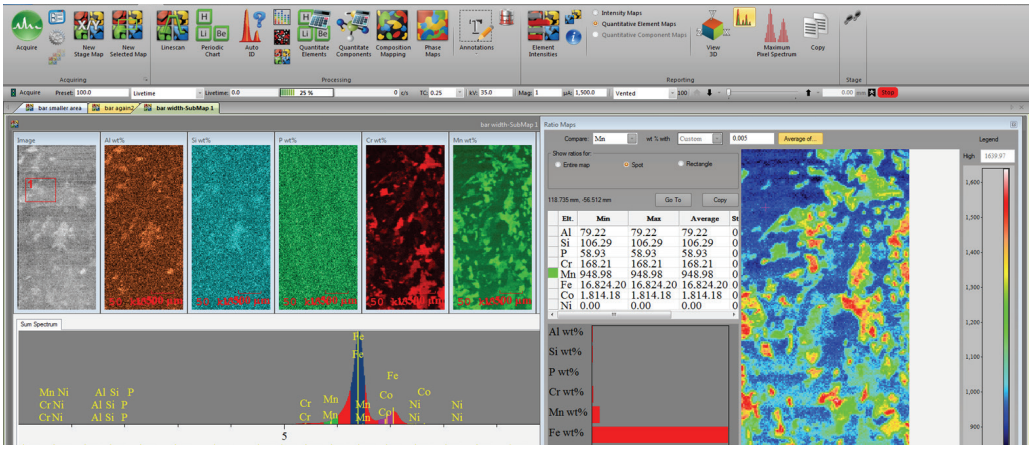
The IXRF Atlas Micro-X-ray- Fluorescence (μXRF) spectrometer system is industry leading in its analytical capabilities:

- Focused X-ray Source from 5 to 100μm
- Largest Sample Stage / Chamber Options Stage X-Y-Z, 25 x 25mm to 600 x 300mm Chambers with Air and Vacuum 508x457x254mm and 950x650x365mm
- High Speed Slew Scanning 1-3ms/pixel with one micron precision all axes
- X-ray source normal to sample surface with multiple detector geometry
- Optimized Optical Viewing System
- 3 Sample Positioning and Analysis Cameras
- Versatile Quantitative Software Program Standardless bulk analysis FP Software Linear Regression, Elements Na — U Quantitative Line Scan and Mapping Thin Film and Coating Metrology Go To Feature—go to any pixel region in map on command to reanalyze
- PC Automated Instrument Control All Parameters—filters, x-ray source kW and mA, cameras, optical microscopes, sample illumination and positioning, and measurement media
- High Resolution SDD Detector options with active areas from 30—150mm^2

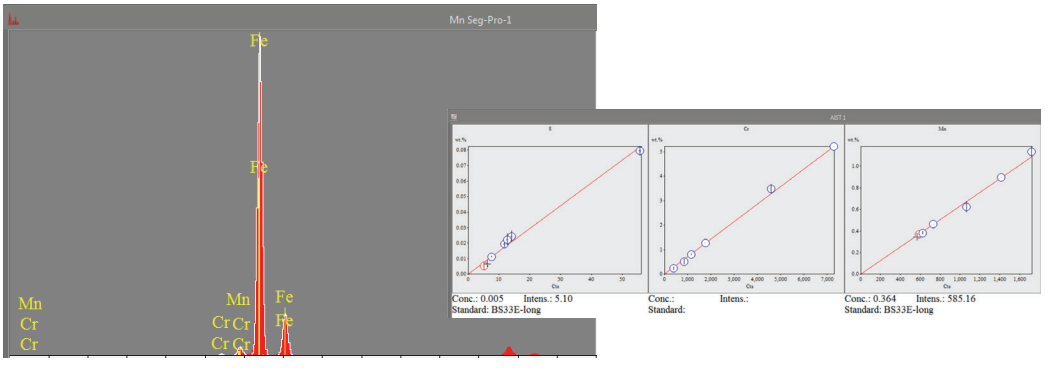
While many key elements co-segregate in continuously cast high strength steels, of particular interest is manganese (Mn) which is the primary hardening agent that can easily be measured in an air environment. Other segregating elements of interest include: Cr, Ni, Mo, S, P, Al and Si.



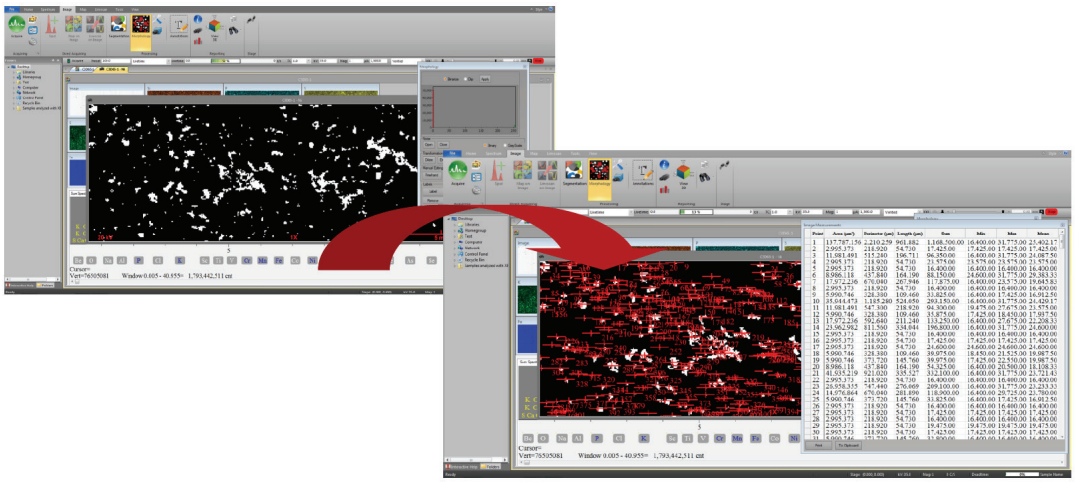
The ATLAS not only provides visual evidence of macrosegregation in elemental maps, but quantitative measurement of elemental concentrations in the centerline region of continuously cast billets and slabs.



Quantification of segregating element concentrations is determined against a range of reference steel standards using linear regression, providing accurate quantitative results. Typical calibration curves for different segregating elements of interest are displayed below.



X-ray elemental maps can also be used to identify and study in greater detail inhomogeneity problems in steels and other materials, natural and manmade, such as inclusions and impurities. Atlas can automatically identify and quantify impurities and inclusions within a map.



The versatile ATLAS mapping software and automated stage control enable unique rapid return on command to map locations of interest with exacting stage relocation precision (one micron). This unique on command "Go-to" feature can rapidly drive the stage to any area of interest, inclusion or inhomogeneity, for further detailed study and/or to confirm initial mapping results. This capability provides corroboration of initial mapping results and the ability to refine mapping results in greater detail if needed or desired. The IXRF Atlas system provides a game changing non-destructive capability for monitoring the homogeneity of natural and manmade materials and how it can affect some of their chemical and structural properties.

See AIST July 2017 Iron and Steel Technology article "Bridging the Gap: MXRF Technique Rapidly Maps Centerline Segregation" by Joydeep Singupta and Jackie Leung, ArcelorMittal Global R&D—Hamilton, Ontario, Canada and K. Witherspoon, IXRF Systems, Inc. Austin, TX for technical details about the advantages of the µXRF technique for quantitative macrosegregation monitoring.

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