Quantification of non-metallic inclusions in steel

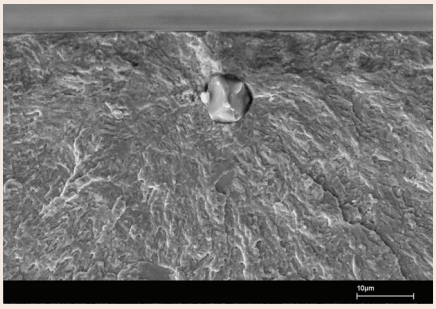
EN10247 – Challenges and opportunities

Recent years have shown a tremendous increase in global steel production. In 2007 approximately 1,344 billion tons of steel have been sold in the marketplace with new manufacturers entering the market to meet the growing demand. However the applications still vary with respect to the properties of the steel and range from standard construction to use in technical high-end products (i.e. Aerospace). It is within this last segment where quality is crucial and minor impurities or defects can cause failure to a component under peak stress or even in routine conditions. Consequently quality control in production and the purchase of steel has gained importance in high end applications as the market offers a wider range of products than in the past.

One of the basic quality issues in steel production is "cleanliness". During the manufacturing process different influencing variables may cause impurities within the product. These predominantly non-metallic inclusions may stem from covering slag on top of the cast or cladding of the oven. Besides these externally produced inclusions, internally generated inclusions may occur through added alloy elements or side reactions with precipitating gases. These inclusions can decrease the steel quality and determine the field of application of the steel. Oxide inclusions for example have a significant higher hardness than the surrounding steel matrix. This could lead to notch effects within a component under stress conditions causing cracks and finally failure. Non-metallic inclusions considerably affect the mechanical properties of steel and impact toughness and fatigue stress. Other important properties such as ductility, machinability, tribologic properties, surface quality and physical properties may strongly vary due to the inclusion content. Different behavior in thermal expansion of the inclusion and surrounding steel matrix for example may lead to the creation of micro-voids initiating cracks and failure.

To avoid failure of components in high-end critical applications and to prevent associated financial consequences due to legal claims an optimum quality in the steel manufacturing and processing industry must be met.

A new European standard EN10247 has been released to cover quality assessment of steel not only manually, but with the aid of an automated microscope system using digital camera technology and image analysis. The EN10247 aims to support high throughput analysis for routine measurement of the inclusion content in steel. The new European standard is based on mathematical relations of inclusions favoring an automated analysis over the time consuming and possibly error prone manual inspection method. Microscope manufacturers have been included in the process of creating this new standard providing system solutions as the EN10247 takes effect.



Scanning electron microscopic image of a 5µm oxide inclusion as a failure initiating site. The component failed due to a fatigue crack which was originated at the top of the unwanted feature in the microstructure within the (535A99) 100Cr6 matrix.

To adequately determine the quality of a steel sample with an automated microscope, such as the Axio Imager.Z2m from Carl Zeiss, sample preparation needs to meet new requirements. Samples with minor preparation imperfections, to a certain extent, can still be analyzed manually as the human eye remains superior in detecting artifacts. As for automated analysis the quality of preparation is of major importance. The optimal planarity of a micro section along with a surface free of stains and scratches is decisive. Although the state of the art software as the AxioVision Module NMI provides sophisticated algorithms to overcome insufficient planarity and even excludes remaining scratches from the evaluation, a proper sample preparation remains irreplaceable. This guarantees efficiency and cuts down laborious post processing. Furthermore it provides highly reproducible and stable results which can not be matched by manual inspection.

The complete microscope system for automated analysis of non-metallic inclusions provided by Carl Zeiss consists of the Axio Imager series microscope with excellent optics and equipped with a digital camera, a motorized stage, PC and software. The system is designed for automatic scanning of a sample area of 200 mm^2, even for several samples, as required in the EN10247. Within the AxioVision software the module NMI provides a guided workflow for user friendly operation in daily routine. Optimized for a special requirement the system is also suitable for many other applications in a materials testing lab.

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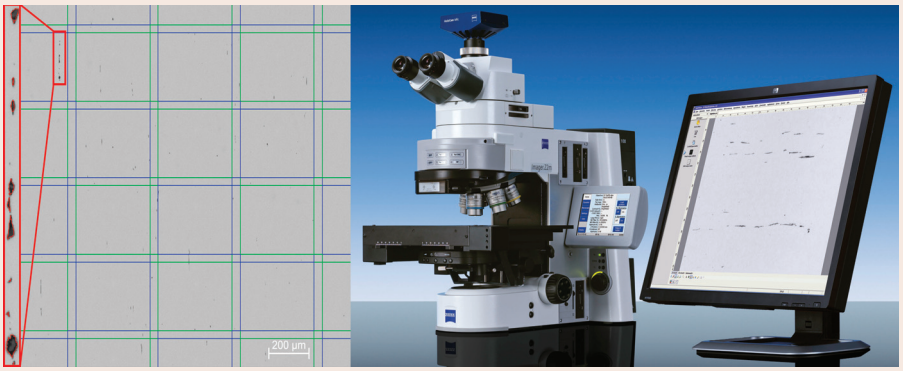

NMI measurement and System NMI. The left hand side shows a tile image of a processed measurement: A critical line of oxide inclusions of 160µm in length (see magnified inset on the left) that has been both automatically detected by the system and combined into one inclusion stringer according to the standard. The right hand side shows a System NMI based on an Axio Imager.Z2m

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