The presence of oxide inclusions in steel has been shown to have a significant impact on fatigue performance of load bearing components manufactured from that steel. It is important to establish some understanding of the connection between:

1. the steelmaking practice
2. the resultant oxide inclusion distribution
3. the corresponding effect on fatigue performance.

The focus of this presentation will be on the relationship between steelmaking practice and measured oxide inclusion population. Values of various steel cleanliness metrics, which provide quantitative information on the macro- and micro-inclusion populations, are compared in steels produced by different processes, including air melt, ESR and VAR. The effects of certain steelmaking process improvements on cleanliness are also reviewed.

**Methods**

**Microinclusions**

- **Microinclusion Cleanliness Measurement Method**
  - **SEM Based Image Analyzer**
  - **Convolutional Neural Network**

- **Microinclusion Cleanliness Measurement Method**
  - **New metrics on inclusion population**
  - **Location**
  - **Geometric**
    - **Shape**
    - **Diameter**
    - **Length**
    - **Width**
  - **Orientation**
    - **Aspect Ratio**
    - **Convexity**
    - **Circularity**

**Conclusions**

- Steelmaking process selection does have a significant influence on inclusion population.
- Traditional cleanliness detection techniques do not adequately measure or screen steel quality to predict component life or reduce failure risk.
- Process development based on advanced measurement methods can achieve enhancements to low-cost steelmaking processes such that they can produce oxide inclusion populations historically only possible from high-cost (remelt) processes.

**References**


**Abstract**

The presence of oxide inclusions in steel has been shown to have a significant impact on fatigue performance of load bearing components manufactured from that steel. It is important to establish some understanding of the connection between:

1. the steelmaking practice
2. the resultant oxide inclusion distribution
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**Objectives**

**Macroinclusions**

- **Project Objective 1**
  - **Given that:**
    - Inclusion related rolling contact fatigue failures in tapered roller bearings have only been found to be caused by large oxide stringers.
    - Today’s clean steels have lower concentrations of oxide stringers.
    - However, there remains variations in the stringer content between “clean” steel sources.
  - **Objective:**
    - Use the appropriate Steel Cleanliness Measurement tool to determine the effect of stringer processing on the macroinclusion population.

**Microinclusions**

- **Project Objective 2**
  - **Given that:**
    - Microinclusions, while not usually associated with rolling contact fatigue failures in bearings, have been found to cause component failures in other applications experiencing other fatigue loading modes.
    - The variation in the microinclusion population in various steel sources is not well understood.
  - **Objective:**
    - Use the appropriate Steel Cleanliness Testing tool to determine the effect of stringer processing on the microinclusion population.

**Results**

**Macroinclusions**

- **Effect of the Steelmaking Process on Macrocleanliness**
  - **The Timken Ultrasonic Test provided:**
    - Large inspection volume
    - Strong correlation with Bearing Life
  - **Utilizing the information provided by the Timken Ultrasonic Test, successful process improvements were implemented over the years to ultimately produce air melt steels with extremely low concentrations of performance damaging oxide stringers.

**Microinclusions**

- **Effect of the Steelmaking Process on Microcleanliness**
  - **Timken has employed recent steel cleanliness measurement technologies to help produce significant reductions in the size of the microinclusion population.**
  - **Improvements to air melt S2100 have approached VAR and VAR VAR levels of cleanliness.**

**References**