Coke and Coal Sizing With AI

Author

Pinak Dattaray, Data Science Team, Ripik AI, Noida, UP, India

Digital technologies are transforming industry at all levels. Steel has the opportunity to lead all heavy industries as an early adopter of specific digital technologies to improve our sustainability and competitiveness. This column is part of AIST's strategy to become the epicenter for steel's digital transformation, by providing a variety of platforms to showcase and disseminate Industry 4.0 knowledge specific for steel manufacturing, from big-picture concepts to specific processes.

Introduction

Coke particle size plays a pivotal role in blast furnace burden preparation, directly impacting permeability, reaction kinetics and thermal efficiency in ironmaking.

Traditional sizing methods, reliant on manual sieving, mechanical screening and off-line sampling, suffer from inconsistencies, operator dependency and delayed feedback, leading to suboptimal charge distribution.

This article introduces Ripik Vision AI, an advanced computer vision and deep learning-driven solution for real-time granulometric analysis in steel plants. Utilizing high-speed imaging, AI-driven edge processing and automated classification algorithms, the system provides high-precision particle distribution monitoring, ensuring uniform coke and coal fractions essential for stable furnace operation and reduced carbon footprint.

By integrating with supervisory control and data acquisition (SCADA), manufacturing execution systems (MES) and process control systems, Ripik Vision AI enables dynamic screen adjustments, minimizes fines generation and optimizes fuel efficiency. This study examines its model training, validation and industrial deployment, highlighting its role in transforming raw material quality control through intelligent automation.

Methodology

Model Architecture

A multilayered structure was used to preprocess the video stream followed by neural network-based models to segment and annotate each individual particle.

Preprocessing:

1. Perspective correction: The conveyor belt is not always parallel to the plane of the lens, i.e., the camera is placed at a non-90-degree angle to the belt to cover a larger area of the belt in the field of view. Due to this, further steps are needed to avoid sizing distortions and account for lens fish-eye effects.
2. Cropping to area of interest: Based on the location of the conveyer belt in the video feed, the footage is cropped and zoomed in into a 1 m x 1 m square area.
3. Gamma correction: Gamma correction redistributes pixel intensity values to either brighten or darken an image while preserving visual details.

Looking for more information on digitalization?

Visit AIST's free Digitalization Applications 101 module at AIST.org/DA101.

Model Layer:

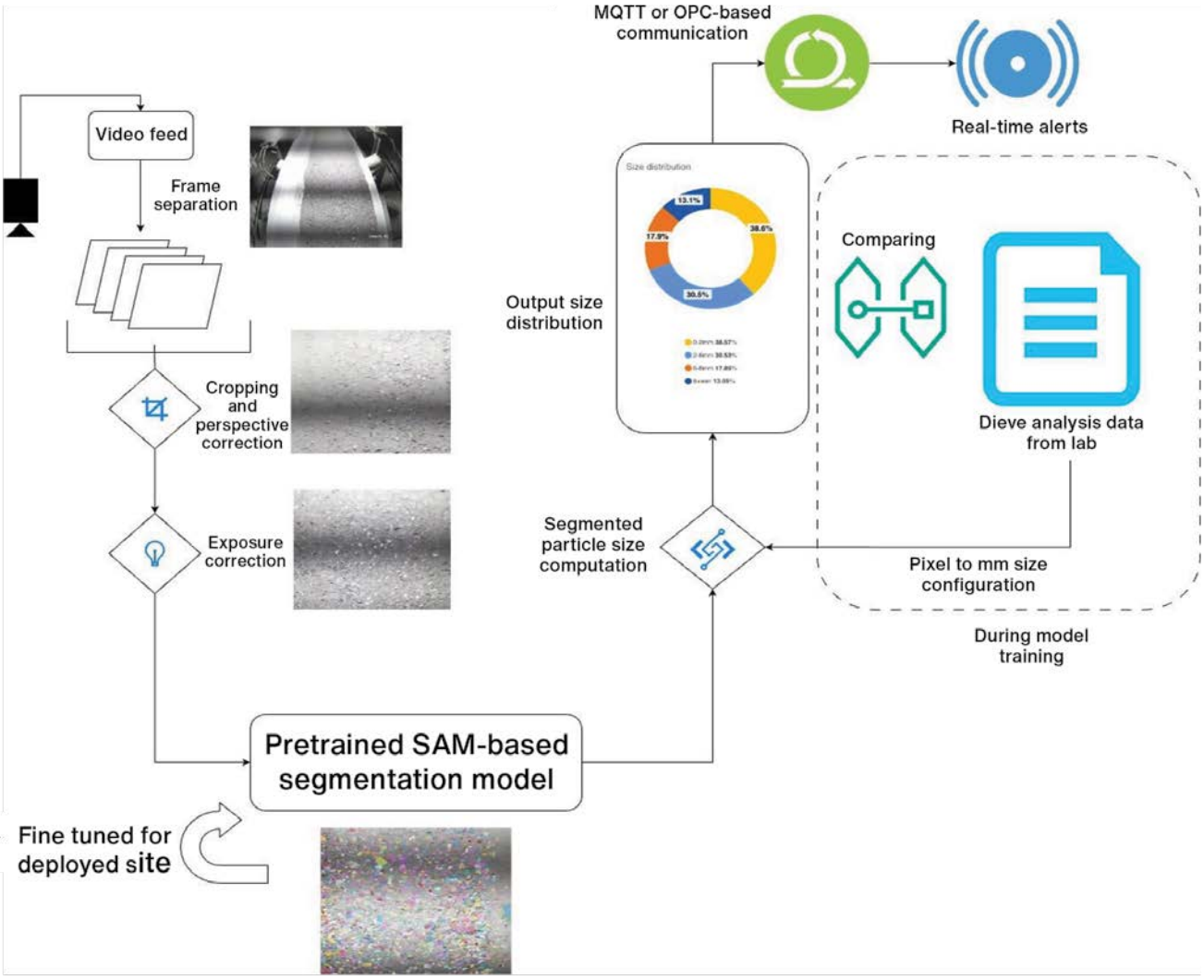
1. Classifier-based model selection: Based on different lighting conditions, different segmentation models were used. These segmentation models are individually tuned to work best during high natural light, high artificial light and mixture of natural/artificial light. The first model runs on incoming images to classify them into types based on the lighting conditions.
2. Segmentation: Segment Anything-like models are used to segment individual particles in each image. These detected segments' pixel clusters are stored as individual elements in arrays for further analysis.

Postprocessing:

1. Segment sizing: A pixel-to-mm/cm value is configured using known item dimensions in the video feed (for example width of the conveyer belt). Each individual segment (identified particle) is allocated a size bucket based on either the following conditions:
   - Longest line based: Longest line that can be drawn within the polygon formed by the particle pixels. The rotating calipers method after identifying a convex hull is used to identify the longest line within each polygon. This reduces the time complexity of the problem to O(n log n) instead of $O(n^2)$.
   - Area of particle based: Application of the shoelace formula gives the area of particle polygon in the feed image in O(n).

Figure 1

Multilayered model for real-time granulometry.



2. Alert-generation: Based on the previous items, alerts are generated for different trigger events.

This multilayered structure is shown in Fig. 1 to give better results than most single-layered models trained over larger data sets.

- Takes care of varying lighting conditions.
- Fast deployment times with immediate results starting as early as the second week of deployment.
- Continuously improving model with closed feedback loop.
- End-to-end software with feed dashboard, alerts and analytics.

Results

From 20 April to 6 May 2024, a coal sizing application powered by computer vision was successfully deployed at the Jindal Steel Angul plant to enhance real-time monitoring and optimization of coal particle distribution. The system utilized AI-driven image processing to analyze coal size variations on conveyor belts, replacing traditional manual sampling methods. During the deployment phase, high-resolution cameras and edge AI devices were strategically positioned along the material handling system to capture and process coal size distribution in real time. The system provided actionable insights, enabling plant operators to detect deviations, optimize crusher settings and improve furnace efficiency. Performance validation was conducted by comparing the computer vision results with lab-based sieve analysis, ensuring accuracy and reliability. The implementation led to improved operational efficiency, reduced manual intervention and enhanced process control, reinforcing Jindal Steel's commitment to AI-driven industrial automation.

Figure 2

Particle size ranging 0–2 mm.

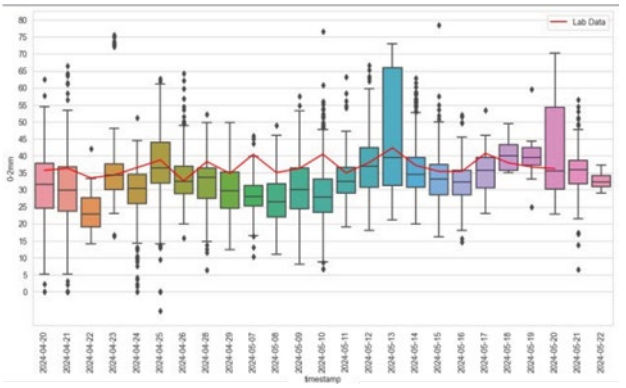


Figure 3

Particle size ranging 2–6 mm.

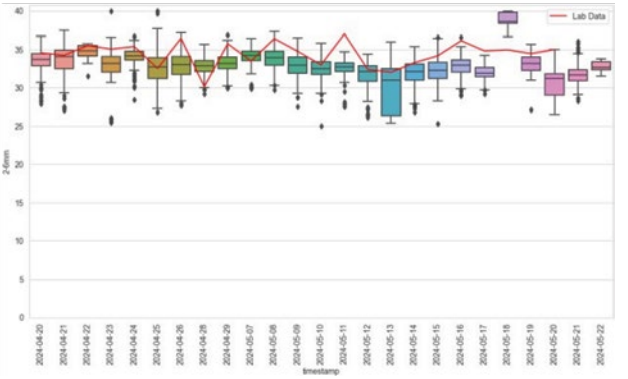


Figure 4

Particle size ranging 6–8 mm.

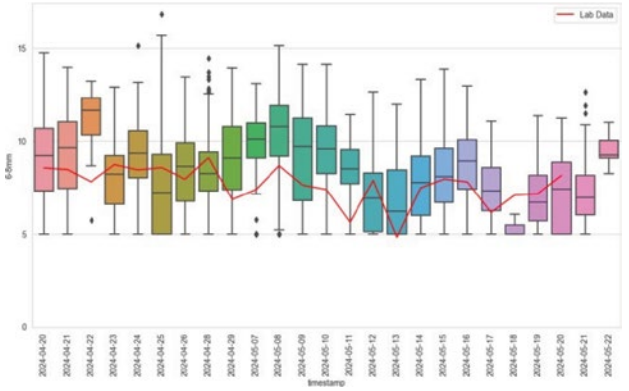
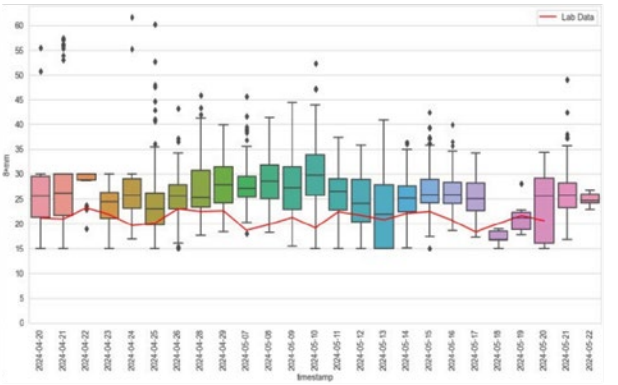


Figure 5

Particle size ranging 8+ mm.



Analysis of Particle Size Fractions (20 April–6 May 2024)

Type: Boxplot with a superimposed red line representing lab data.

X-Axis (Timestamp): All charts' x-axis represents dates from 20 April 2024 to 6 May 2024.

Y-Axis (Particle Size Range): The percentage composition of the 0–2 mm, 2–6 mm, 6–8 mm and 8+ mm size fraction.

Variation and Outliers

- 0–2 mm Size Fraction:
  - The interquartile range (IQR) fluctuates across the dates, indicating variations in the spread.
  - Multiple outliers (black dots) beyond the whiskers suggest occasional extreme values.
  - Some days show high variability, while others have a more stable distribution.
- 2–6 mm Size Fraction:
  - Displays relatively lower variation compared to the 0–2 mm fraction.
  - Fewer extreme outliers indicate a more consistent distribution.
  - The median remains stable with minor fluctuations.
- 6–8 mm Size Fraction:
  - Shows higher variability compared to the 2–6 mm fraction.
  - Numerous outliers suggest an inconsistent distribution.
  - A downward trend in median values is observed in early May, followed by a rise.
- 8 mm+ Size Fraction:
  - Exhibits the highest variability among all size fractions.
  - Several extreme outliers are present, particularly in early May.
  - The median fluctuates significantly over time.

Lab Data Trend

- 0–2 mm Size Fraction: The lab data (red line) fluctuates but mostly stays within the IQR range.
- 2–6 mm Size Fraction: The red line closely follows the median of the distribution, indicating alignment with the observed data.
- 6–8 mm Size Fraction: The red line shows fluctuations but generally follows the trend of the boxplots.
- 8+ mm Size Fraction: The red line constantly stays below the median and mostly below the IQR range as well.

Conclusion

Lab data which is sampled three times a day (once per shift) is a small sample and not a good representation of the overall bulk material. The lab results closely follow the real-time analysis for medium-sized particles, i.e., 2–6 mm and 6–8 mm bucket, but the lab results misinterpret/underestimates the larger particles which are sparser in the bulk material (8+ mm). These are the larger particles which contribute to the LOI % (unburnt material resulting in bed ash, fly ash).

Due to the use of Ripik's real-time coal particle size distribution measurement system, the client has been able to reduce their loss of ignition by 0.5%, saving them over 18,000 tons of coal in a year. ✦

AISTech The original version of this paper was presented at AISTech 2025 — The Iron & Steel Technology Conference and Exposition, Nashville, Tenn., USA, and published in the AISTech 2025 Conference Proceedings.

Did You Know?

SMS group to Deliver Europe's First Continuous Mill Technology to UMB Steel

SMS group announced it will deliver Europe's first continuous mill technology (CMT® 700) to steel manufacturer UMB Steel s.r.l.'s site in Oțelu Roșu, Romania.

The companies said the new long products mill will be added to the existing steelmaking complex and operate in a continuous endless process. SMS will deliver mechanical, electrical and automation systems for the integration. The CMT 700 will have an estimated capacity of 700,000 metric tons annually of straight bars, compact coils and wire rod.

The CMT technology is estimated to reduce CO_2 emissions by up to 30% because no natural gas is required for billet reheating. With its vertical compact coil (VCC®) system, wire rod line and straight bar finishing area, the plant can have a flexible production mix.

The new continuous caster's technological features include the CONREX mold tube and CONDRIVE mold oscillation. It will also incorporate TBK REBARgauge.

This is the first collaboration between the two companies.