Use of AI in Automated Billet Quality Assessment

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Abstract

RUSAL, a leading global aluminium producer has revolutionized the microstructure analysis of aluminium ingots by implementing artificial intelligence (AI). Developed by RUSAL's Engineering and Technology Center, this AI-driven system utilizes machine vision and deep learning to assess billet quality, significantly reducing analysis time to just 15 minutes. This technology enhances quality control and minimizes manual tasks, ensuring durability and performance in industries such as construction, mechanical engineering, and aerospace.

The AI system evaluates cylindrical ingots, a high-demand aluminium product, across eight key microstructural parameters, including grain size and inclusions. Traditional analysis methods can take up to four hours, whereas the AI system delivers comprehensive reports rapidly. This advancement demonstrates the transformative impact of industrial AI on quality control processes.

Operational at the RUSAL Engineering Center laboratory, the technology is set to be deployed in aluminium smelter laboratories for real-time quality assessment. Each parameter is analysed by dedicated neural networks trained on annotated digital microscope images, achieving accuracy comparable to trained technicians while eliminating human error. This ensures consistent quality control and optimal material performance across various industries.

Keywords: Neural networks and deep learning, Microstructure analysis, Aluminium billet, Machine vision, Artificial intelligence and quality control.

1. Introduction

Extrusion billets made from 6xxx series alloys represent advanced, high-quality products in today's aluminium industry. Beyond essential factors like chemical composition, surface quality, geometry, and macrostructure, microstructure stands as a critical performance characteristic. Its quality directly affects extrudability, anodized surface quality, and the mechanical properties of the final profile. Specific, defined microstructural features distinguish high-quality billets from poor ones. The measurement and rating of these features form an established standard: the Billet Microstructure Quality Assessment.

1.1 Billet Microstructure Quality Assessment

The main controlled parameters of the microstructure are:

- Number and size of inclusions;
- Inverse segregation zone size;
- Grain size;
- Porosity volume fraction and size;
- Degree of transformation and fragmentation of AlFeSi-particles;
- Number of Mg_2Si particles;
- Distribution type of secondary Mg_2Si particles.

As shown in Table 1, each of the above parameters influences the extrusion process and the quality of the produced aluminium profiles.

Table 1. Microstructure parameters influence on extrusion process and product quality [1, 8, 11, 13-25].

Process	Microstructure parameter						
	Number and size of inclusions	Inverse segregation zone size	Grain size	Porosity volume fraction and size	Degree of transformation and fragmentation of AlFeSi-particles	Number of Mg_2Si particles	Distribution type of secondary Mg_2Si particles
Extrusion							
Extrusion speed	-	-	significant	-	severe	severe	severe
Pick-ups	some	-	-	-	severe	significant	-
Surface Roughness	severe	some	-	significant	significant	some	-
Die lines	significant	some	-	-	significant	-	-
Blisters	some	-	-	significant	-	-	-
Tearing	some	significant	-	-	significant	some	-
Die bearing condition	severe	some	-	-	significant	-	-
Weld seams and back-end defect	some	severe	-	-	-	-	-
Mechanical properties							
Tensile strength	some	-	some	-	-	severe	severe
Yield strength	some	-	some	-	-	severe	severe
Elongation	some	-	some	-	-	severe	severe
Hardness	some	-	some	-	-	severe	severe
Anodizing response							
Surface dullness	-	-	-	some	significant	severe	severe
Colour match	-	-	-	-	significant	severe	severe
Streaks	-	-	significant	-	-	-	-

*According to data received from ETC Scientific and Analytical: The actual analysis time depends on PC speed and network connection and may vary among users. These factors influence the speed at which microstructure images are transferred to the server and responses are received.

5. Initial Role Out and Next Steps

Since the beginning of 2025, AMAS has operated on RUSAL ETC's central server, where a powerful video card is the main component for operating and training analysis models. AMAS is currently undergoing industrial testing and is being used for quality control of the microstructure of 6xxx series alloy billets, running in parallel with the current microscope software analysis.

AMAS is expected to launch at all five RUSAL billet producing plants in 2025–2026. The existing server capacity is expected to meet the needs of all the company's laboratories. However, the computing power required is still to be demonstrated.

6. Conclusions and Learnings

The developed system of automatic microstructure analysis (AMAS) for 6xxx series extrusion billets is comprehensive software that uses computer vision technologies and neural network models to automatically survey and analyse microstructure parameters without operator participation. This system completely eliminates the influence of the human factor on the result.

Using the developed AMAS significantly reduces the time needed to analyse key microstructure parameters of 6xxx series billets and ensures results comparable to those obtained by operators using image analysis software in most scenarios.

The results obtained indicate the viability and potential of unattended microstructural analysis using AMAS. The accuracy of AMAS improves with an increased dataset for training neural network analysis models.

7. Possible Risks

While AMAS analysis models are fully functional (excluding inclusion analysis) and deliver satisfactory lab results, their performance on plant laboratory equipment still requires validation. Adaptation during implementation may be necessary to ensure compatibility across diverse operating conditions.

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